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NASA CR-156798

5K70SK AUTOMATICALLY TUNED, HIGH-POWER, S-BAND KLYSTRON

**Art Goldfinger
Varian Associates, Inc.
611 Hansen Way
Palo Alto, Ca. 94303**

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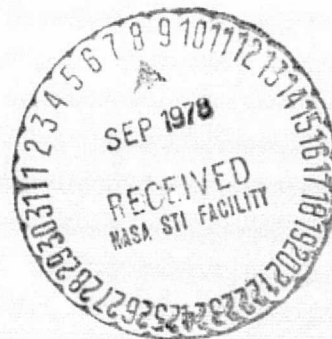
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PREFACE

The purpose of this report is to present final engineering documentation for work completed under NASA Contract No. NAS5-20601.

The scope of work directed by the contract included the delivery of 44 5K70SK amplifier klystrons and 26 remote tuning units with demonstrated performance governed by NASA Specification No. 73-15029. Spare parts were supplied as directed by the contract.

With one exception, the 5K70SK klystron and tuner met or exceeded the requirements of Specification No. 73-15029. 10,000-cycle tuning capability was not demonstrated. Because of system restraints on interchangeability, no recommendations on design change can be made at this time.

One design change was made to facilitate broadband tuning under test conditions.

The program was undertaken by Varian Associates, Inc., Palo Alto, California, and directed by Mr. Art Goldfinger of Varian.

Technical supervision and direction from NASA Goddard Space Flight Center was administered by Mr. Howard Kingman of NASA.

TABLE OF CONTENTS

<u>Section</u>	<u>Page No.</u>
1. INTRODUCTION	1
1.1 Background Information.	1
1.2 Present Program Outlined	2
2. ELECTRICAL AND MECHANICAL SPECIFICATIONS	3
2.1 Broadband Klystron - Electrical	3
2.2 Remote Tuner - Electrical.	5
2.3 Broadband Klystron - Mechanical.	7
2.4 Remote Tuner - Mechanical	8
2.5 Specification Sheet, 5K70SK	9
3. ENGINEERING TESTS	13
3.1 Cavity Tuner Tests	13
4. DESIGN MODIFICATION TO MEET SPECIFICATIONS	19
5. INSTALLATION, OPERATING AND TUNING PROCEDURES	23
5.1 Step Tuner Installation on H-193 Magnetic Circuit	23
5.2 Preparing Step Tuner for Operation	25
5.3 "Zero" Indexing of the 5K70SK Klystron	27
5.4 Field Tuning or Trim Tuning of the 5K70SK.	30
6. RELIABILITY ANALYSIS OF AMPLIFIER KLYSTRON 5K70SK	37
6.1 Reliability Data, 5K70SG	37
7. PRECAUTIONS TO INSURE RELIABILITY	43
7.1 Uncrating Instructions for 5K70SK	43
7.2 Installation and Operating Precautions	44
7.3 Recommended Failure Form for Users	50
8. DESIGN VERIFICATION TESTS	53

APPENDIX: SUPPLEMENTAL ENGINEERING INFORMATION

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LIST OF ILLUSTRATIONS

<u>Figure No.</u>		<u>Page No.</u>
2-1	Specification Sheet, 5K70SK.	10
3-1	Sliding Contact Mechanism for the 5K70SK	14
3-2	Tuner Cycling Test Setup	15
4-1	Effect of Input Cavity Q_E Variations on Stagger-tuned Bandpass . .	20
4-2	Resistively Loaded Ceramic	21
5-1	Step Tuner Installation	24
5-2	Sample Test Data Card	26
5-3	Klystron Zero Index	28
5-4	Typical Channel Bandpass at Low Power	32
5-5	Typical Channel Bandpass at High Power	35
6-1	5K70SG Failure Modes - 24 Tubes.	38
6-2	5K70SK Estimated Tube Performance	41
7-1	Vacuum Pressure vs VacIon Current	49
7-2	Recommended Failure Form	51

1. INTRODUCTION

1.1 BACKGROUND INFORMATION

Early in 1965 Eitel-McCullough, Inc., (now the Eimac Division of Varian Associates, Inc.) developed the 5K70SG amplifier klystron for use in the unified S-band communications system. The 5K70SG was to provide communications for the Apollo moon exploration program. Bandwidth requirements (10 MHz, 1 dB) imposed on the 5K70SG were then modest and easily achieved, and from 1965 to date the 5K70SG has demonstrated creditable field performance.

In 1971, system requirements indicated that an amplifier with 22 MHz, 1 dB bandwidth would be extremely useful, if not mandatory, in supporting various lunar missions separated in frequency by 17 MHz. The 5K70SG requires field tuning to accommodate this frequency span. A development contract, NAS5-20307, was awarded to Varian to modify the 5K70SG to provide the desired 22 MHz bandwidth. The work was successfully completed in a five-month period, and a modified tube was delivered. The type designation for the new klystron was 5K70SG-WB. This klystron was both physically and electrically interchangeable with the 5K70SG.

In 1972, because of expanded system requirements and the need for more sophisticated tuning methods, a new contract was awarded Collins Radio of Dallas, Texas (NAS5-20375) to provide the necessary system upgrading. The project became a joint effort involving Collins Radio, Varian, and the Summit Engineering Corporation of Bozeman, Montana.

The purpose of the project was to provide a klystron amplifier-tuner package that would:

1. Extend the existing band coverage, 2090 MHz - 2120 MHz, to a new band covering 2025 - 2120.
2. Provide a 22 MHz, 1 dB bandpass at any place within the extended range.

3. Provide the 22 MHz, 1 dB bandpass by means of a pushbutton activated, remotely controlled tuning device.

The new klystron amplifier was to be directly interchangeable both electrically and mechanically with the 5K70SG, and the remote control tuning device compatible with the 5K70SG focusing magnet.

All tasks were successfully completed in early 1974 with the delivery of one retrofit transmitter. The new klystron amplifier designation was 5K70SK; the remote tuning unit was Summit Engineering Corporation's Model 8191A step tuner. It was this development work which led to the present contract.

1.2 PRESENT PROGRAM OUTLINED

The primary and major effort of this program was the production and delivery of 44 amplifier klystrons, 26 remote tuning units, and appropriate spare parts to service the tuning units. Several additional tasks were completed during the report period along with normal engineering and production tests. The following detailed discussion of the program includes the items listed below:

1. Electrical and mechanical specifications
2. Results of cavity tuner cycling tests
3. Results of engineering tests (DVT)
4. Design change to meet specification
5. Installation procedure
6. Operating and tuning procedures
7. A reliability analysis of the amplifier klystron

2. ELECTRICAL AND MECHANICAL SPECIFICATIONS

The electrical and mechanical performance specifications given for the 5K70SK amplifier klystron and remote tuning units are outlined below.

2.1 BROADBAND KLYSTRON - ELECTRICAL

2.1.1 Tuning Range

The tube shall tune from a center frequency of 2031 MHz to 2116 MHz.

2.1.2 Bandwidth

The instantaneous bandwidth shall be 20 MHz minimum to the 1 dB points and shall decrease monotonically outside of the band to the point of minimum gain.

2.1.3 Bandpass Ripple

Maximum ripple in the bandpass shall not exceed ± 0.5 dB. The bandpass characteristics shall vary smoothly over the bandpass without discontinuities. Maximum gain slope shall not exceed 0.5 dB/MHz.

2.1.4 Power Output

Shall be variable from 1 kW to a minimum saturated power output of 24 kW. Requirements of 2.1.2 and 2.1.3 shall be met over the power output range without retuning.

2.1.5 Gain

Minimum gain shall be 45 dB across the bandpass.

2.1.6 Load VSWR

The tube shall meet all performance specifications operating into a load with a VSWR up to 1.1:1.

2.1.7 Input VSWR

The tube shall meet all performance specifications with a source input VSWR up to 1.1:1.

2.1.8 Random AM Noise

Random AM noise shall be at least 60 dB below carrier output level.

2.1.9 Spurious Output

All spurious output signals (excluding harmonics and AM spectral lines) shall be 85 dB below the carrier output reference level.

2.1.10 Linearity

With a 2 kW level output produced by each of two separate simultaneous tones, separated in frequency by 1.5 MHz to 24 MHz, all intermodulation products shall be at least 30 dB below the 2 kW reference level.

2.1.11 Output Power Stability

Power variation over a 24 hour period shall be less than ± 0.2 dB.

2.1.12 Warmup Time

The maximum time from initial turn-on to power output shall be five (5) minutes.

2.1.13 Efficiency

Minimum efficiency shall be 37% at 24 kW output, 17% at 12 kW output, and 1.5% at the 1.2 kW level.

2.1.14 Filament Supply

Filament power requirements shall not exceed 7.5 Vdc at 13 A.

2.1.15 Vac-Ion Pump

A VacIon® pump shall be incorporated as an integral part of the klystron for maintaining and determining the vacuum integrity.

2.1.16 Electromagnet Focus Supply

The maximum power requirement for the Varian H-193 focus magnet supply shall be 200 Vdc at 25 A.

2.1.17 Beam Voltage

The maximum beam voltage requirement shall not exceed 22 kVdc.

2.1.18 Beam Current

The maximum beam current shall not exceed 2.78 amperes.

2.2 REMOTE TUNER - ELECTRICAL

2.2.1 Input Power

Input voltage shall be 115 Vac $\pm 10\%$, 60 Hz. Total input power shall be 350 W or less.

2.2.2 Interlock

Provisions shall be made to prevent drive power from being applied to the tube during the tuning cycle. An indicator shall be provided to indicate tuning in process.

2.2.3 Controls

Pushbutton controls shall be provided for six channels. The pushbutton actuated will remain lighted to indicate the channel selected. A set of preset selection switches shall be provided for presetting the tuning position of each cavity for each of the six channels.

2.2.4 Remote Control

Provision shall be made to permit tuning via momentary dry contact closures (either manual or computer controlled) originating at locations up to 500 feet away.

2.2.5 Configuration

The remote tuner shall be a digital positioning device. "Standard" off-the-shelf modules and components will be used where possible, and all integrated circuits and transistors shall plug into standard sockets for ease of replacement. All components shall be adequately identified on the circuit cards so they may be easily located on the system schematics.

2.2.6 Tuning Time

Maximum tuning time shall be 60 seconds.

2.2.7 Setup

For purposes of initial setup, the numbers acquired from the tuning shaft turns indicators by manually tuning the klystron for a passband characteristic within the specifications paragraphs 2.1.1 through 2.1.3, will provide the same passband within specifications in the automatic mode when these numbers are transferred to the present switches of the automatic tuner.

2.2.8 Retrievability

Numbers characteristic of a particular passband will provide that passband repeatedly via the automatic tuner when entered into the present switches.

2.2.9 Memory

It will not be required to actuate the automatic tuner, nor will the automatic tuner automatically actuate when the system is first turned on to achieve the passband to which the system was tuned when it was last operated.

2.3 BROADBAND KLYSTRON - MECHANICAL

2.3.1 Operating Position

The tube and tuner shall be operated in any spatial orientation without degradation of its operational characteristics.

2.3.2 Input RF Connector

The rf input connector shall be Type N.

2.3.3 Output RF Coupling

The output rf coupling shall be UG435A/U flange.

2.3.4 Cooling

The cathode shall be forced-air cooled and the body and collector shall be cooled with water of a 50/50 solution of water and ethylene glycol. Coolant flow rates, pressure drops, and connections shall be compatible with the existing power amplifier system, which uses a Varian 5K70SG klystron.

2.3.5 Tuning Life

The tuning mechanism of the klystron and tuner will have a demonstrated life expectancy to permit in excess of 10,000 tuning cycles between extremes of the tuning range while meeting all specifications described herein. Provisions shall be made for manual tuning in case of tuner failure.

2.3.6 Configuration

All critical mechanical features which involve tube interchangeability, such as exterior dimensions and interface connections, shall be identical to the Varian 5K70SQ to permit a direct interchange of the tubes. Other items which do not affect direct interchangeability may vary.

2.3.7 Operational Environment

The tube and tuner will operate without degradation in performance in an ambient temperature range from 0° F to +120° F.

2.4 REMOTE TUNER - MECHANICAL

2.4.1 Tuner Assembly Size

The tuner assembly maximum dimensions shall not exceed 14" high by 14" wide and shall not extend more than 15" from the center line of the magnet toward the front of the cabinet. The configuration must provide easy accessibility to the coupling shafts between the tuner and tube for convenient alignment and hookup of the tube and tuner assembly.

2.4.2 Tuner Power Supply

An external power supply may be furnished if the supply will mount conveniently within the present USB power amplifier cabinet without required modifications or interference with existing components. Dimensions of the power supply shall not exceed 13" deep by 6" high by 8" wide. The power connection to the power supply will be on the 6" by 8" face.

2.4.3 Interface

The tuner assembly shall bolt directly to the Varian H-193 magnet assembly using the existing bolt hole patterns for the magnet. No modifications will be required either to the magnet assembly or the tuner assembly to effect this interface except for the possibility of using longer fasteners which will be supplied with the tuner.

2.5 SPECIFICATION SHEET, 5K70SK

A specification sheet is included as Figure 2-1.



varian

5K70SK
April 12, 1977

SPECIFICATION ELECTRON TUBE TYPE 5K70SK

DESCRIPTION: Wide Band, CW Klystron Amplifier, Five Integral Cavities, Magnetically Focused, Liquid and Forced Air Cooled Unipotential Cathode, 2025 - 2120 MHz

RATING: Absolute Maximum, Note 1:

Parameter:	Ef	Eb	Ib	Iby	Pcol	VSWR	tk	Cooling	Altitude
Unit:	Vac	kVdc	Adc	mAdc	kW	Load	sec(min)		Ft
CW (FM):	7.5±5% Note 2	22	3.2	75	70	1.5:1	300	Note 3	15 K

TEST
CONDITIONS: 7.5 22(max) --- --- --- 1.1:1 (max) 300 Note 3 ---

MOUNTING POSITION: Any ELECTRICAL CONNECTIONS: Note 12

WEIGHT (Approximate): 100 pounds

GENERAL

Ref	Test	Conditions	Symbol	Limits		Units
				Min	Max	
[D-30(b)]	Dimensions	Per Outline Drawing		---	---	

QUALIFICATION (Notes 4 and 5)

QUALITY CONFORMANCE INSPECTION, PART 1 (Note 9)

Heater Current		If:	9.5	13	Aac
Pressure Drop	Water Flow:	Pres:	---	65	psi
	Body Section = 1.2 gpm	Pres:	---	40	psi
	Collector = 18.5 gpm				
Static Pressure	Note 6	Pres:	---	125	psig

Figure 2-1. Specification Sheet, 5K70SK

QUALITY CONFORMANCE INSPECTION, PART 1 (note 9) con't

Ref	Test	Condition	Symbol	Min	Max	Units
4250	Power Output (1)	CW RF Power Amplifier Pd = 750 mW (max) Im = 25 Adc (max) Notes 7, 8, & 9	Po l:	24	---	kW
			Eff l:	40	---	%
			Gain l:	45	---	dB
			BW l:	20	---	MHz
			Ib l:	---	3.2	Adc
			Iby l:	---	75	mAdc
4214	Emission	Power Output (1); Pd = 0, Eb = 20 kVdc Note 10	Δ Ib:	---	200	mAdc
	Tuner Torque	Note 11	tq:	---	80	in-oz

Reference numbers not enclosed in parentheses refer to paragraphs in MIL-STD-1311A, "Test Methods for Electron Tubes." References shown in parentheses refer to paragraphs in MIL-E-1G, "Military Specification for Electron Tubes." Only those paragraphs of MIL-STD-1311A and MIL-E-1G referenced in this specification shall apply.

Note 1: For the proper use of these ratings, refer to MIL-E-1G, Paragraph 6.5.

Abbreviations of electrical terms used in this specification which are not adequately defined in MIL-E-1G, Appendix B, are defined as follows:

Eb	dc beam voltage	Im	dc electromagnet current
Ib	dc beam current	Pcol	collector-power dissipation
Iby	dc body current		N.B. - All dc voltages refer to the cathode.

Note 2: The heater surge current shall not exceed 24 amperes.

Note 3: The cooling requirement for operation at maximum ratings at sea level and an ambient air temperature of 30°C are as follows:

	FLOW	PRESSURE DROP
Collector	18.5 gpm (min)	40 psi
Body and Output Section (series connected)	1.2 gpm (min)	65 psi
Gun forced air	20 cfm	

The maximum allowable outlet liquid-coolant temperature is 80°C.

The maximum allowable water pressure shall not exceed 125 psi.

During electrical tests, cooling water shall not exceed the minimum flow rates and maximum pressure drop indicated above.

Figure 2-1. Specification Sheet, 5K70SK (continued)

Page 2 of 3

- Note 4: These tests and all other tests specified herein shall be applied to two sample tubes, unless otherwise specified, which are representative of production quality. These tests shall not be construed as lot acceptance tests.
- Note 5: Tests specified as qualification tests shall not be performed as quality conformance tests. However, when a design change is made which affects the operating characteristics of the tube, these tests, together with all quality conformance tests shall be applied to two tubes selected at random from the first production lot incorporating the design change.
- Note 6: The water system will be static pressure checked at 125 psi for a minimum of 5 minutes. There shall be no leaks.
- Note 7: Adjustment of the electromagnet current, and the circuit tuning shall be permitted to obtain the desired operating conditions.
- Note 8: These tests to be performed with the tube mounted in the H-193 Varian klystron circuit assembly or equivalent.
- Note 9: The bandwidth will be measured at 1.0 dB points and shall be free of spurious oscillation. Ripple and small discontinuities shall be less than 1 dB.
- Note 10: The tube shall be allowed to stabilize at the specified conditions for at least 15 minutes, after which the heater voltage shall be reduced to 6.75 Vac. After 15 minutes of stabilization at this reduced heater voltage, the beam current shall be measured and the change in beam current (ΔI_b) shall be no greater than the specified value.
- Note 11: The shaft shall be run to each stop and then backed off one-quarter turn. The torque required to start the shaft shall not be more than that specified.
- Note 12: HEATER POLARITY

In those applications where DC heater voltage is used the following heater supply polarity is mandatory. The common heater-cathode lead (normally white) must be connected to the positive side of the heater supply (and to the negative side of the DC beam supply).

Failure to comply with this polarity rating and requirement will result in extremely low heater life.

3. ENGINEERING TESTS

3.1 CAVITY TUNER TESTS

To demonstrate conformance with paragraph 2.3.5 (10,000 cycle tuning life), special tuning cycle tests were performed on a series of klystron cavities.

The cavities were constructed and processed in a manner identical to that of a complete klystron amplifier; i.e., they were brazed, processed (vacuum pumpdown and bakeout) and equipped with a VacIon pump for vacuum monitoring.

During the tests, critical performance characteristics were monitored to determine whether or not changes were taking place throughout the cycling period. The characteristics measured were frequency, Q_0 , tuning screw torque, and vacuum. The first indication of vacuum pressure rise was to be considered end-of-life for the vacuum bellows. Any erratic behavior in the frequency repeatability of the tuner was to be considered end-of-life for the sliding contact within the cavity.

Figure 3-1 is a photograph of the sliding contact mechanism used in the 5K70SK. Although the tungsten wire sliding contact mechanism has been used extensively at Varian, this particular configuration had never been life-test cycled prior to these tests. This mechanism and the vacuum bellows which permits tuner motion within the klystron were the only areas of concern prior to the cycling tests.

Figure 3-2 is a block diagram describing the cycling test setup. As shown, the VacIon pump power supply was arranged with an alarm circuit to stop the cycling mechanism in the event of a vacuum pressure rise. This gave an exact cycle count at the time of bellows failure. Cycling was stopped at various times to check frequency and Q_0 at a precise position of the tuning screw to determine frequency repeatability and/or degradation of the tungsten wire contacts.

Three separate tests were conducted. The variable for each test was the total travel of the sliding contact tuner. The travel of the tuner and the extension of the vacuum bellows are directly related.

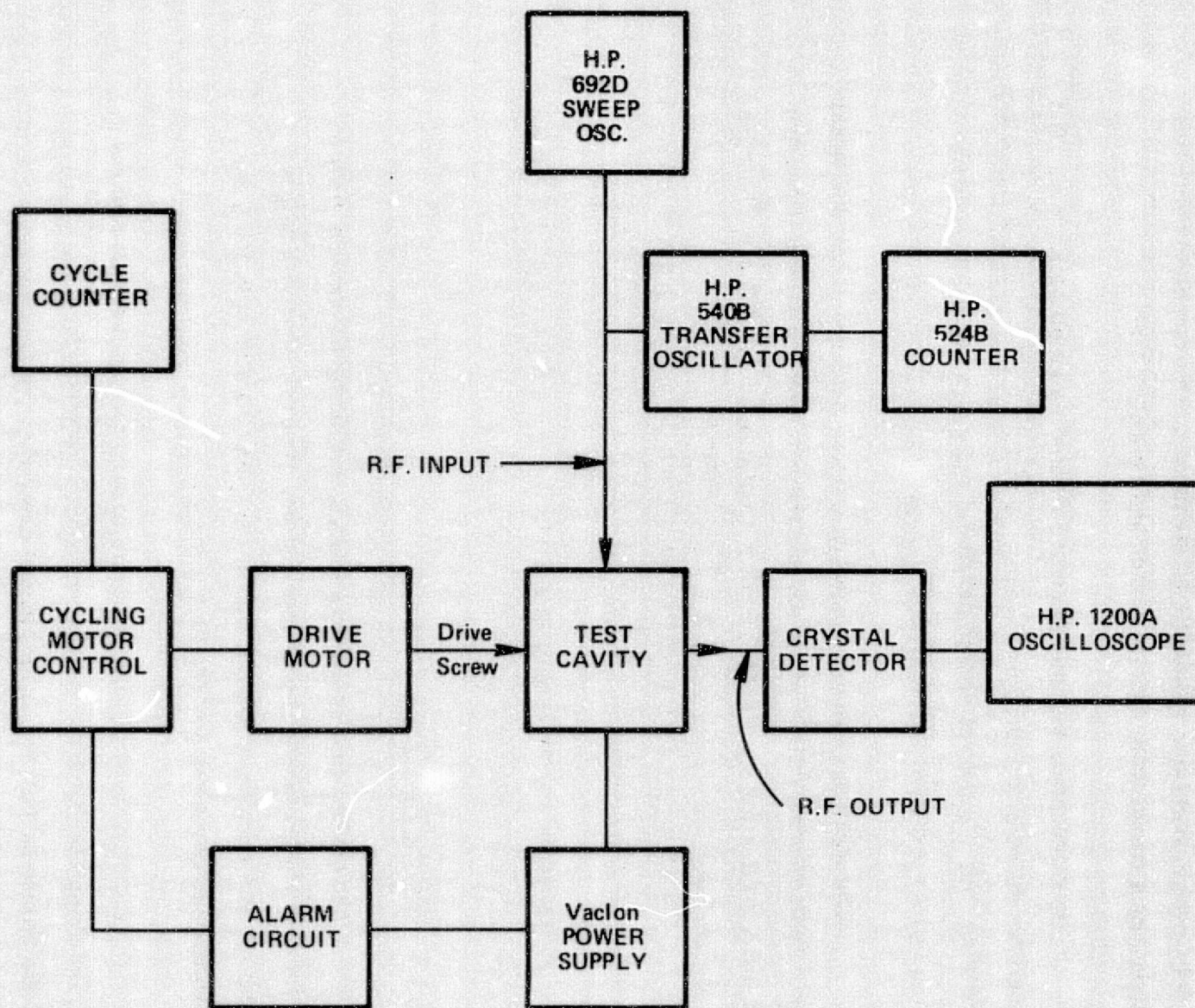


Figure 3-2. Tuner Cycling Test Setup

3.1.1 Cycling Test No. 1

The first test was conducted with a tuner travel of 0.500 inch, 0.150 inch longer than the actual travel required to cover the desired tuning range. The 0.150" was added to represent a suitable safety factor. One complete cycle was accomplished by a travel from 0.0" to 0.500" and return to 0.0".

In retrospect, the safety factor included was a bit optimistic. The vacuum bellows failed at 2,549 cycles because of metal fatigue. This early failure was surprising, but was not yet viewed pessimistically because it was a single-experiment failure and other tests were to follow.

The other parameters measured gave no evidence of any additional problems. Tuning repeatability was good, and the extreme of repeatability error was 0.62 MHz, well within the limits required to produce a specification bandpass.

Tuner torque increased gradually early in the test from 48 in/oz. to 60 in/oz, but leveled off at the higher figure during the duration of the test.

Q_o of the cavity remained essentially constant throughout the test, indicating no increase in the sliding contact resistance.

3.1.2 Cycling Test No. 2

The cycling test cavity was rebuilt, replacing the vacuum bellows and the complete sliding contact tuner mechanism. The previously mentioned "safety factor" was eliminated and the tuner travel was limited to 0.350", the amount required to cover the desired tuning range.

The same type of fatigue failure caused the new vacuum bellows to leak at 3,183 completed cycles. Because the nature of the failure was identical to that of the failure in Test No. 1, it became clear that this was not simply a random failure. Both tests combined gave definite proof that the bellows could not complete 10,000 cycles.

Again, the other parameters of the test showed no problems. Tuner torque and Q_o showed no measurable change. Frequency repeatability was slightly better than on the first test and showed an extreme error of 0.5 MHz.

3.1.3 Cycling Test No. 3

The third cycling test was performed to provide one additional data point and, at the same time, provide data for a condition which more realistically represented cycling conditions expected in field operation.

The first two tests were run using the travel required to tune from one band extreme to the other and return. It is not likely that, in field operation, every tuning cycle would travel to these extremes. A more likely pattern would be an averaging of short travel cycles (channel 1 to zero and return to channel 2) and long travel cycles (channel 6 to zero and return to channel 5). This average travel would be exactly one half the travel experienced in test No. 2, i.e., $\frac{0.350''}{2} = 0.175$.

Test No. 3 was conducted to observe this "half travel" effect on cycling life.

A completely new cavity was constructed for this test so that the "tracks" cut by the sliding contact in tests No. 1 and No. 2 would not alter the test results. The cavity was evacuated and processed as in previous tests.

The test was terminated at 10,710 cycles because of vacuum bellows failure. As in the two previous tests, metal fatigue was the cause of failure.

No other degradation could be seen. Tuner torque and cavity Q_o remained constant throughout the test. The maximum frequency repeatability error was 0.37 MHz.

In short, the three cycling tests showed rather conclusively that no problem other than vacuum bellows failure could be anticipated from extended cycling life.

Consultations with a number of vacuum bellows manufacturers were held, but no solution to the problem could be found. In order to extend the cycling life of the bellows, either larger-diameter bellows or bellows with a greater number of convolutions would have to be used.

A larger-diameter bellows is not permissible because the electrical design of the klystron determines the spacing between cavities and thus limits bellows diameter.

Bellows with more convolutions require more physical space in a direction perpendicular to the axis of the klystron. Any physical expansion in this direction would require a design that was not physically interchangeable with the existing 5K70SG klystron. Since electrical and mechanical interchangeability were absolute requirements, no design remedy could be implemented.

Since it is not a proven fact that 10,000 extreme to extreme cycles will be required for satisfactory system performance, the matter of nonconformance is in abeyance. Varian has contractually agreed to repair, at no charge, any klystron whose life has been shortened by vacuum bellows failure within the 10,000 cycle limit.

If system operation proves that 10,000 extreme to extreme cycles are an absolute requirement, a klystron can be designed to meet the need; however, it would not be interchangeable with the existing 5K70SG klystron. A new electro-magnet design would be required to accommodate the new klystron design.

4. DESIGN MODIFICATION TO MEET SPECIFICATIONS

During the course of early production testing of the 5K70SK, considerable time and effort was devoted to obtaining the desired 20 MHz bandpass. 20 MHz could be obtained with effort; but in some cases, little or no safety factor was available. Because of the normally expected differences between factory test equipment and equipment available at site installations, this marginality would almost certainly produce sub-specification performance at some sites.

A single variable, the input cavity Q_E , was found to be the cause of tube-to-tube bandpass variations. Despite stringent electrical controls on the input coaxial drive cable and close mechanical tolerances on the input loop assembly, Q_E variations in the input cavity were still large enough to create problems in stagger-tuned broadbanding.

Figure 4-1 shows the effect of these input cavity Q_E variations on the 20 MHz bandpass.

To overcome this problem, an adjustable resistive load was incorporated within the input cavity. This mechanism is shown in Figure 4-2.

The device provides external adjustment of the input cavity Q in an operational klystron. Q changes are made by adjusting the depth of penetration, within the input cavity, of the resistively loaded ceramic shown in Figure 4-2.

This added adjustment provided the flexibility needed to simplify the broadbanding procedure. Considerably less time is spent in factory testing and the final results show increases of 2 to 3 MHz of bandwidth in some cases.

This design improvement has the added advantage of being permanent; that is, once adjusted and locked, no further adjustment is ever required.

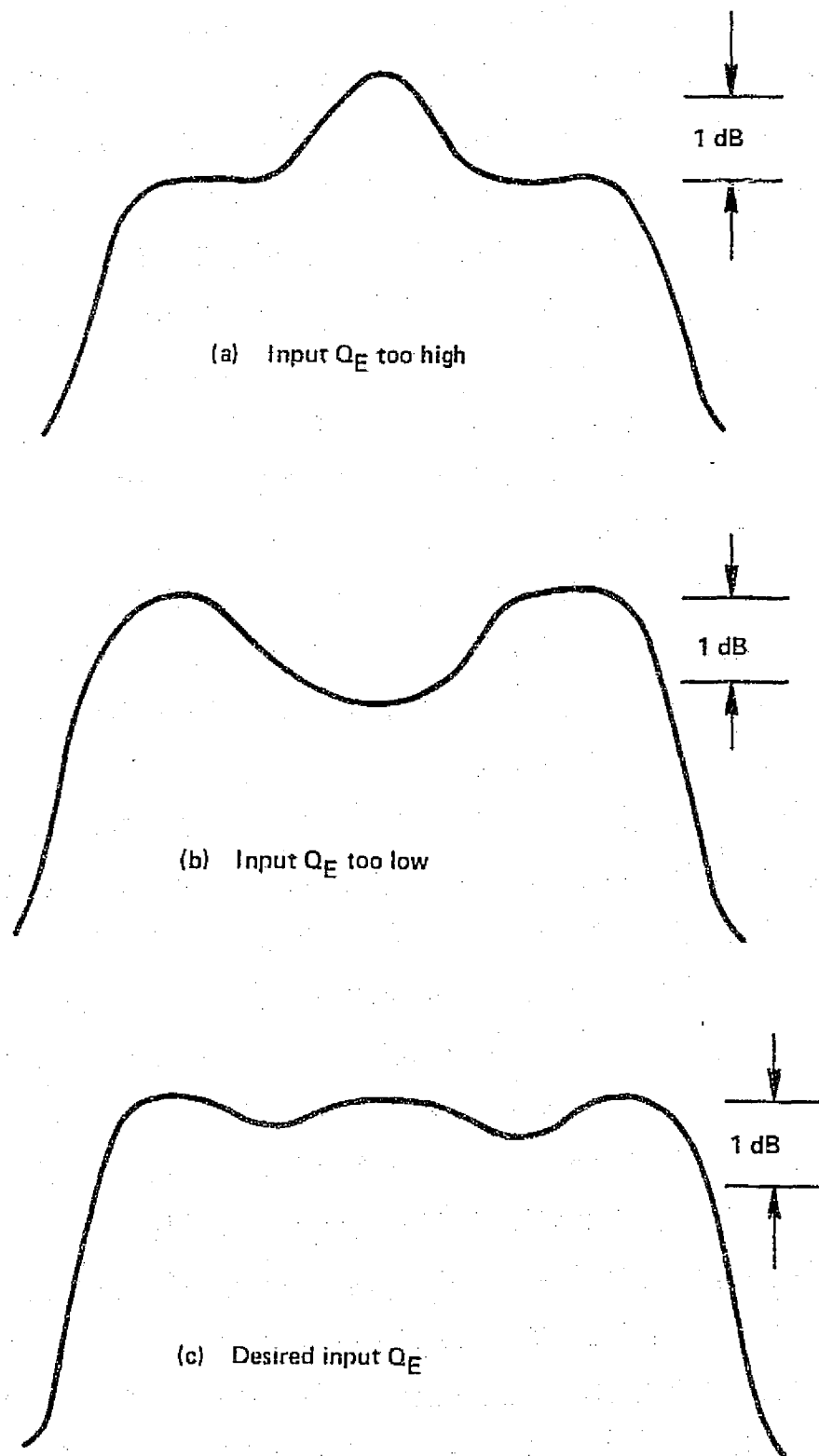


Figure 4-1. Effect of Input Cavity Q_E Variations on Stagger-Tuned Bandpass

5. INSTALLATION, OPERATING AND TUNING PROCEDURES

The Varian klystrons 5K70SG and 5K70SK are essentially identical in mechanical configuration and are electrically and mechanically interchangeable in the S-band amplifier subsystem Model 11-076. The general instructions for installation of these klystrons in their magnetic circuits and preparation for use is covered completely in Technical Manual ME-1505, Section 2, and will not be repeated here.

The following paragraphs deal only with those changes in installation and operating procedures unique to the newly developed 5K70SK klystron and the Summit Engineering step tuning unit Model No. 8191A.

5.1 STEP TUNER INSTALLATION ON H-193 MAGNETIC CIRCUIT (SEE FIGURE 5-1)

1. Rotate each of the 5 Dzus fasteners (located in the front panel of the 8191A) 1/4 turn counterclockwise, and swing the front panel assembly open until it latches at the 90° position.
2. Loosen the 10-32 hex socket head screws in the split collar which clamps the five drive shafts to the drive sprocket hubs.
3. Using the roll pin handle provided, pull the shaft extensions toward the front of the step tuner assembly until the front surface of the helical coupler in the shaft assembly contacts the rear of the hub.
4. Set all of the turns counters (adjacent to the tuner knobs) to "000".
The proper procedure for setting "000" is as follows:

Rotate tuner knobs in a counterclockwise direction until counters have passed through "000" to "995". Return to "000" in a clockwise direction.

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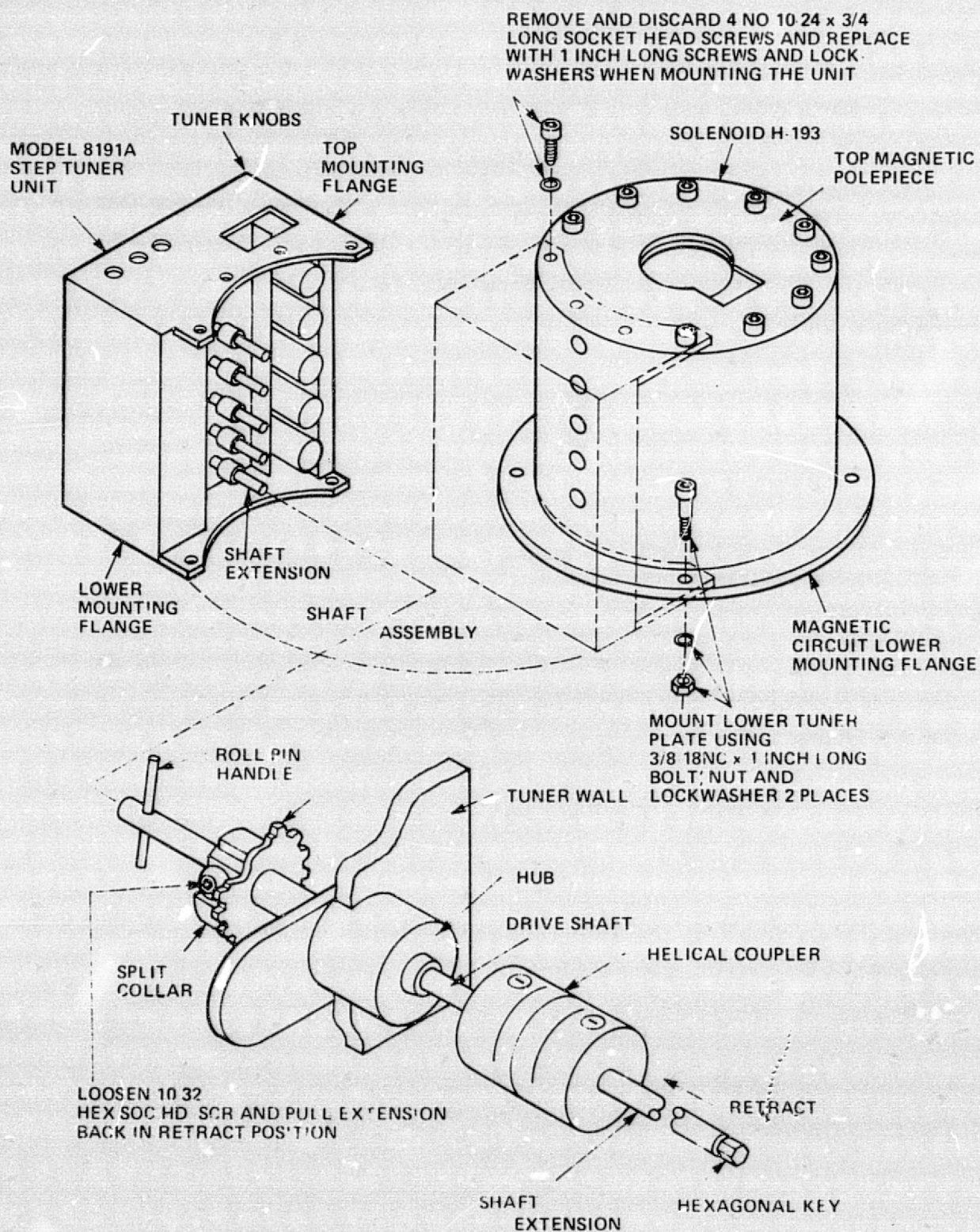


Figure 5-1. Step Tuner Installation

5. Remove four 10-24 x 3/4" socket head screws securing the top magnetic polepiece to the magnetic return cylinder.

6. Position the step tuner unit so that the four holes in the tuner top mounting flange are aligned with the four 10-24 tapped holes in the magnetic circuit and secure with the four 10-24 x 1" socket head replacement screws (NOTE: Some units will only employ two screws). Do not tighten screws.

7. The lower mounting flange of the step tuner is secured to the lower mounting flange of the magnetic circuit with two 3/8-18 x 1" bolts using nuts and lockwashers. After tightening the 3/8" bolts, tighten the 10-24 x 1" screws securing the top mounting flange of the step tuning unit.

8. Assuming the 5K70SK klystron has been "zero" indexed (Section 5.3), engage the hexagonal key on the shaft extension with the hexagonal socket of the klystron tuner screw. This is done by sliding the shaft through the sprocket hub assembly and simultaneously rotating the shaft in a counterclockwise direction until the hexagonal sections mate. Care must be exercised during this process to insure that the "zero" indexing of the klystron is not disturbed.

9. After engagement of the hexagonal shaft extension and the klystron tuning screw, recheck the "000" position of the turns counters. If they have been disturbed, return to "000" as in Paragraph 4.

10. While maintaining a slight inward and counterclockwise pressure on the shaft extension, tighten the 10-32 hex socket head screws on the split collar that locks the sprocket hub to the drive shaft.

5.2 PREPARING STEP TUNER FOR OPERATION

After installation of the step tuner unit and engagement with the klystron amplifier, the thumbwheel counters on the front of the step tuner unit may be set to agree with the thumbwheel counter settings given on the test data card (see Figure 5-2).

TUBE TYPE 5K70SK
 TUBE SERIAL NO. 1R-1
 ZERO INDEX 4 TURNS FROM C.W. STOP
 STEP TUNER THUMBWHEEL SETTING

		A	B	C	D	E
CHANNEL	1	370	234	128	098	163
	2	447	368	265	235	310
	3	544	494	387	371	430
	4	621	591	502	483	543
	5	693	638	608	585	648
	6	754	709	694	679	734

Figure 5-2. Sample Test Data Card

The thumbwheel counter settings represent the proper klystron cavity tuning to establish a 20 MHz bandpass centered on the following frequencies:

Channel 1	2035 MHz
Channel 2	2050
Channel 3	2065
Channel 4	2080
Channel 5	2095
Channel 6	2110

After setting all thumbwheel counters to agree with readings given on the test data card, engage the three interconnecting cables to the three input jacks found on the top surface of the step tuner unit. Functions of the three jacks are:

J13	28 Vdc power input
J14	Parallel connector for remote panel
J15	Relay closure for de-energizing rf drive during channel change

After connection is made to J13, the channel tuner is ready for operation. When energized with 28 Vdc, the tuner unit may select an arbitrary channel or may remain stationary with a red light indicating tuning in process. In either case, merely depress the pushbutton for desired channel and it will be tuned automatically.

5.3 "ZERO" INDEXING OF THE 5K70SK KLYSTRON

The 5K70SK klystron will be shipped from Varian in a pre-tuned zero-indexed condition. The following paragraph describes the procedure for establishing the zero index.

During factory setup, all cavity tuners are rotated clockwise to a positive stop which represents the end travel of the cavity tuner. At this point, an indicator flag is welded to the tuning screw to provide alignment between the tuning screw and a scribe line on the housing of the tuner assembly (see Figure 5-3). This setting

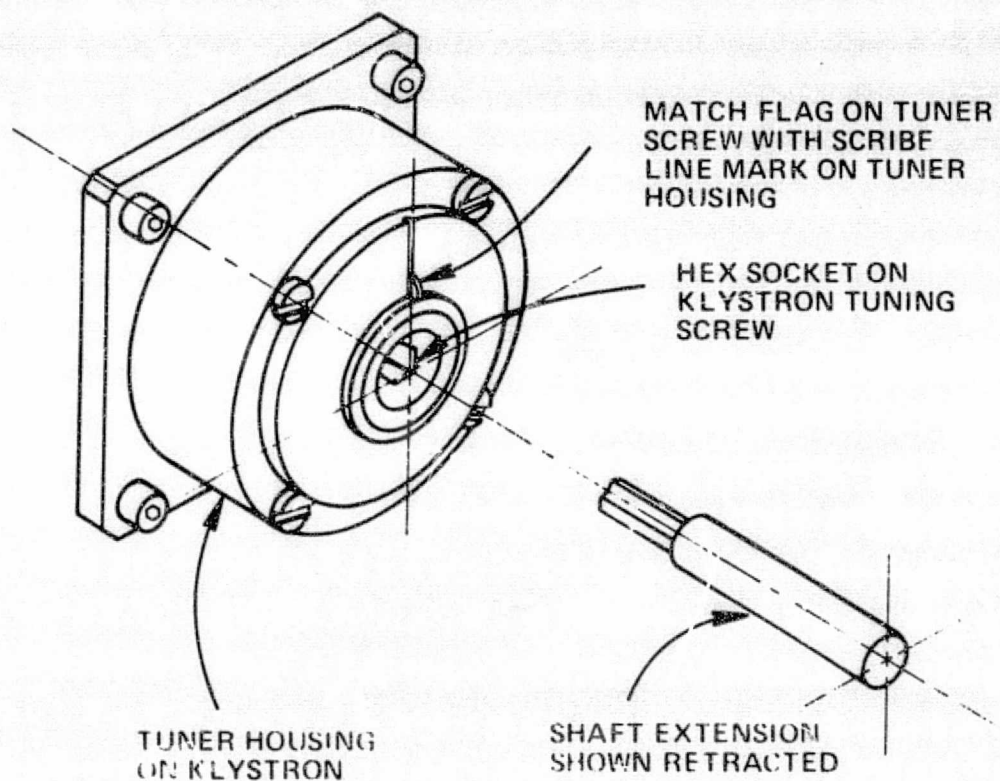


Figure 5-3. Klystron Zero Index

is not the zero index referred to in the preceding paragraph. The zero index is a factory-determined number of turns rotated counterclockwise away from the positive clockwise stop.

For example, on 5K70SK Serial No. 1R-1 all tuners were zero indexed at 4 turns counterclockwise from the fully clockwise positive stop. The number of turns required to establish the zero index was recorded on the test data card accompanying 5K70SK, Serial No. 1R-1 shown in Figure 5 2. Not all tubes will necessarily be zero indexed at 4 turns counterclockwise, nor will all tuners on a particular tube have the same index numbers. The purpose of the zero index is to establish a reference between factory tuners and field tuners. This arbitrary stop also establishes the required tuning range while limiting the vacuum bellows to the minimum possible flexure. This limitation of flexure has a powerful effect on the life of the vacuum bellows.

In the event that one or more klystron tuner screws become misindexed with the 8191A tuning unit during operational service, the following procedure will re-establish proper zero indexing of the klystron cavities with the 8191A tuner unit.

1. Open the front panel door of the 8191A tuner unit.
2. Loosen each of the five hexagonal 10-32 socket head screws which tighten the split clamps and sprocket hubs to the drive shaft assemblies.
3. Retract each of the drive shafts, disengaging the hex end of each shaft from the hex socket in the tuner screw of the klystron tube.
4. Place the "zero latch" toggle switch of the 8191A tuner unit, located on the motherboard and to the right of the battery holder, in the down position and press any of the six channel-select buttons. This will return all of the drive mechanisms to zero position.
5. Disconnect power to the 8191A tuner by removing the power supply cable connector from the top of the tuner, or by switching off the ac source to the power supply.
6. Loosen the four 10-32 x 1" socket head screws and the two 3/8-18 x 1" bolts which secure the top and bottom plates of the tuner to the klystron magnet circuit. (NOTE: Some units will only have two screws). Carefully remove the screws and lift the tuner from the magnet frame.

7. With the tuner removed, the five hex socket klystron tuning screws and flags are visible through the holes in the magnet assembly.
8. Re-establish zero indexing of klystron by turning the klystron tuning screws to the clockwise position stop using the 3/16" T handle Allen wrench provided (VACO No. 79212). Then rotate the tuning screws counterclockwise the number of turns recorded on the test data card, until the indicator flag welded to the tuning screw and the scribe line are precisely aligned.

— NOTE —

Alignment must be approached from the counterclockwise direction. If alignment is "over-shot", rotate two full turns counterclockwise and reapproach alignment from the counterclockwise direction.

9. After zero indexing of the klystron is complete, the 8191A tuning mechanism can be reinstalled as described in the installation instructions of Section 5.1.

5.4 FIELD TUNING OR TRIM TUNING OF THE 5K70SK

The foregoing sections dealing with the installation and operation of the 5K70SK and 8191A tuning unit are based on the assumption that factory performance will be exactly duplicated at site installations. However, experience has shown that because of differences between factory test equipment and operational site equipment, exact duplication of bandpass curves is not always possible without some readjustment at the site installations.

The following section deals with field adjustments (trimming) and change of channel frequencies.

5.4.1 Factory Tuning and Establishment of Thumbwheel Counter Settings

In the event that field retuning or "trimming" is required, it is necessary to understand how the thumbwheel counter settings are originally established under factory-tuned conditions.

Individual channel bandpass characteristics are factory established using sweep generators in conjunction with a broadband detector/oscilloscope combination.

Shown in Figure 5-4 are typical klystron cavity positions for proper operation on Channel 1 (frequency centered on 2035 MHz). The bandpass shown in Figure 5-4 is typical of the bandpass to be expected with small-signal input of approximately 10 mW.

Cavities C and D on all channels form the upper and lower band edges and are placed at approximately +10 MHz and -10 MHz, respectively. Cavities A and E are roughly centered on the channel center frequency. Cavity B is above band center and affects the bandpass only to a small degree, but has a strong effect on the overall gain of the klystron.

The bandpass is obtained by hand tuning the 5 knobs found on the front of the step tuner unit. When the hand tuning process is finished, the turns counters coupled to the stepping motor shaft will give a readout which is directly transferred to the thumbwheel counters for Channel 1.

After transferring turns counter reading to thumbwheels, automatic operation on Channel 1 is checked by depressing any other channel pushbutton, then quickly redepressing the Channel 1 pushbutton. During this procedure, the step tuner will return to "000", reverse, and return to Channel 1. If bandpass characteristics are correct, nothing further is done, and the process is repeated on Channel 2. If bandpass characteristics are not correct, retrimming is required, in which case slightly different turns counter readings will be obtained. These new readings are then transferred to thumbwheel settings for Channel 1.

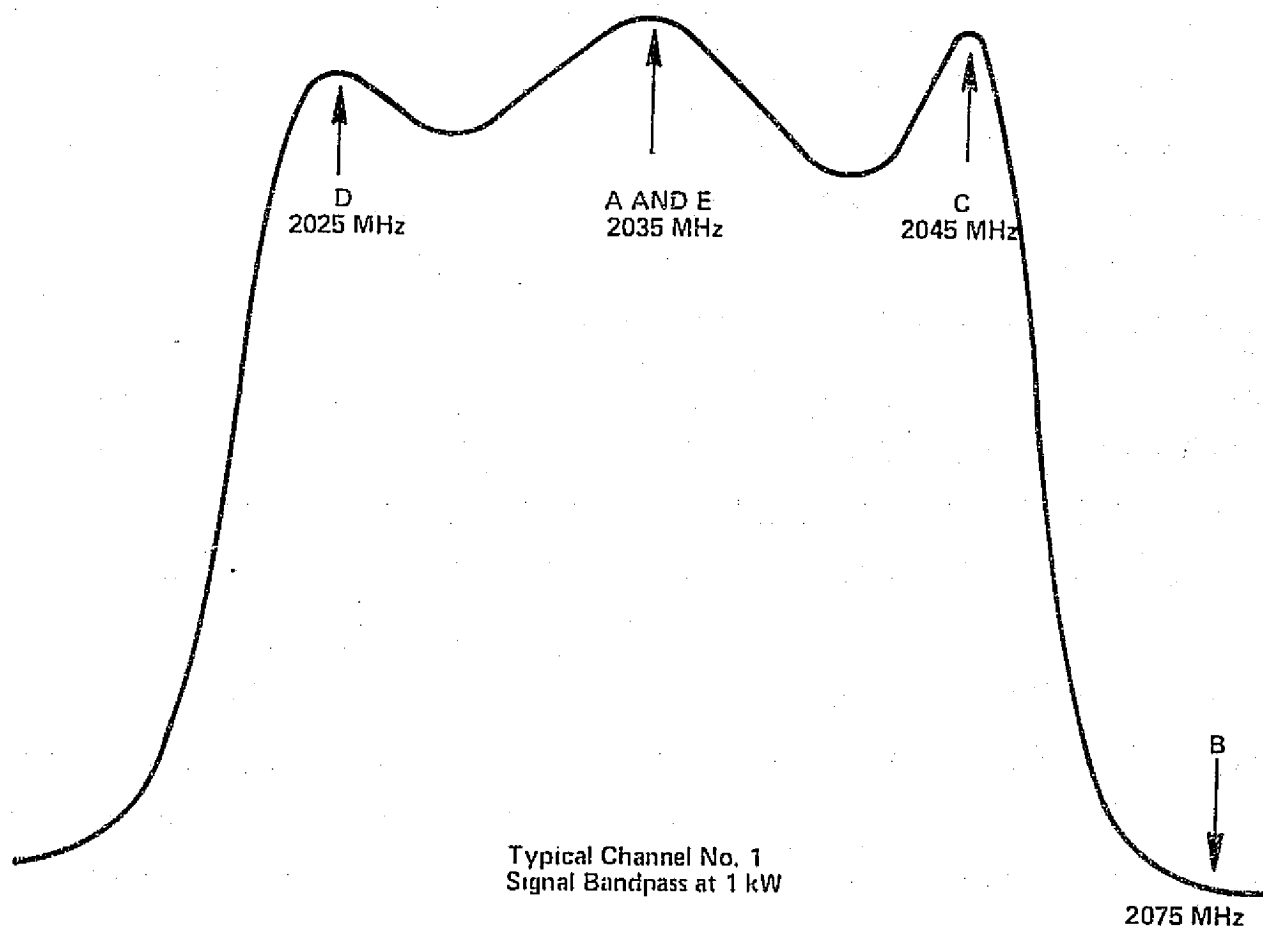


Figure 5-4. Typical Channel Bandpass at Low Power

IMPORTANT NOTE

In order to maintain repeatability, all final cavity tuning adjustments are made by turning the tuning knob in the clockwise direction. If it is necessary to make a frequency adjustment requiring a counterclockwise rotation of the tuning knob, it is necessary to "overshoot" in the counterclockwise direction and return to the proper position in a clockwise direction.

5.4.2 Field Retuning

The most probable causes for variation between factory performance and site performance are the differences normally experienced in the input drive line chain and the output transmission circuit.

Input line mismatches (VSWR) alter both the frequency response (Q) and the actual frequency of the input cavity of the klystron. Output line mismatches (VSWR) likewise alter the frequency response (Q) and the actual frequency of the output cavity of the klystron.

If factory bandpass performance cannot be obtained, the most likely readjustments are the tuning of the input or output cavities or both. These readjustments can only be made properly using sweep frequency oscilloscope observation techniques.

Adjustments of the input cavity (E) and the output cavity (A) have a similar effect on the frequency bandpass of the klystron. Both affect the center of the response and the overall tilt of the bandpass. Only experience and practice at tuning these cavities will produce desired performance.

In general, all adjustments should be made at low level (1 kW), striving to duplicate the response shown in Figure 5-4.

When final adjustments are made, remembering always to approach these final settings from a clockwise direction, the readjusted turns counter readings should be immediately transferred to the thumbwheels.

Final performance must, of course, be checked at the 20 kW level and minor adjustments may again have to be made at this high power level to provide a compromise setting which produces specification performance at both high and lower power levels.

Bandpass characteristics at high power are shown in Figure 5-5.

Cavities B, C and D should never need retuning because their response and frequency are unalterable by external circuitry.

If factory-determined thumbwheel settings do not result in the proper placement of cavities B, C and D, mis-indexing of the tuning unit or slippage of the couplings between the tuning unit and the klystron has taken place.

Proper indexing of cavities D and C is easily checked by observing a bandpass pattern such as shown in Figure 5-4. These cavities should be at the bandpass edges ± 10 MHz from band center.

Indexing of cavity B can be checked by comparing the gain ($10 \log \frac{P_o}{P_d}$) obtained at the factory with that obtained at the operational site. If the gain of the klystron is lower than factory tests indicate, cavity B is too high in frequency. If the gain of the klystron is higher than factory tests indicate, cavity B is too low in frequency.

5.4.3 Channel Frequency Change

Tuning curves of frequency or channel number versus thumbwheel settings are provided with each 5K70SK klystron. Should it be desired to tune to frequencies other than those provided by factory thumbwheel settings, new channel frequencies can be established by interpolation from these curves.

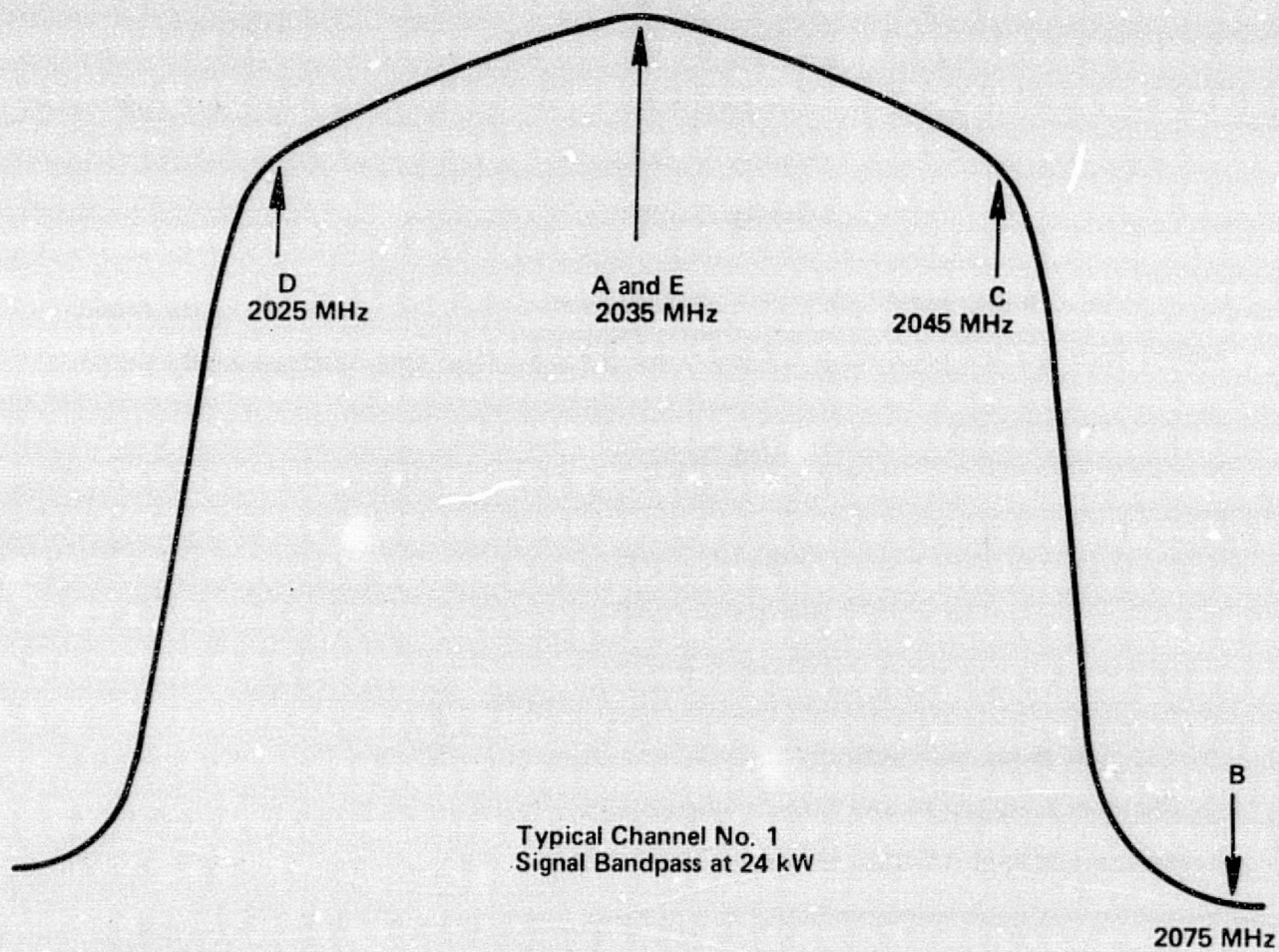


Figure 5-5. Typical Channel Bandpass at High Power

Example: Referring to tuning curves (Design Verification Tests, Section 8, page 23), it can be seen that the thumbwheel cavity settings for Channel 3 (centered at 2065 MHz) are as follows:

Cavity A = 390

Cavity B = 310

Cavity C = 404

Cavity D = 460

Cavity E = 370

In order to establish a new channel centered on 2070 MHz, the new thumbwheel settings are read directly from the curves. The new settings would be:

Cavity A = 412

Cavity B = 345

Cavity C = 436

Cavity D = 500

Cavity E = 409

Simply dial these new settings into the thumbwheel switches. If you are operating on Channel 3, depress any other channel button for an instant and immediately repress the Channel 3 button to achieve a new Channel 3 operating frequency of 2070 MHz. To obtain optimum performance, retrimming, as previously described, may be required.

6. RELIABILITY ANALYSIS OF AMPLIFIER KLYSTRON 5K70SK

The reliability analysis and predictions presented here are based on a comparison between the field tested 5K70SG and the newly developed 5K70SK.

With the exception of the tuning mechanism, which includes a new vacuum bellows and sliding short tuner, the 5K70SK is essentially identical to the 5K70SG.

Because the tuning mechanism is a major departure from the original 5K70SG design, its performance has been given special scrutiny in the engineering tests performed as outlined in Section 3. The only measurement of reliability will be given by accumulated field data taken with actual channel usage.

Reliability analysis of the other major components of the 5K70SK (electron gun, body, rf window, collector) is based on field performance of the 5K70SG. Supportive data, compiled over an eleven-year period, are presented in Section 6.1.

6.1 RELIABILITY DATA, 5K70SG

The mean time between failure (MTBF) is calculated here by dividing the total estimated operating hours by the number of tube failures.

Over an eleven-year period, twenty-four tubes were returned to Varian. Four of these tubes were tested and found to meet full specification performance. Of the remaining tubes analyzed, nine failures were considered to be system induced (cracked output windows, melted drift tubes, other external physical damage) and the tubes were eliminated from the calculation. The failure mode for all twenty-four tubes is shown in Figure 6-1.

MTBF for the eleven remaining tubes was calculated on the basis of eleven-year operation at fourteen sites. Seven-day, eight-hour, fifty-two week operation was assumed.

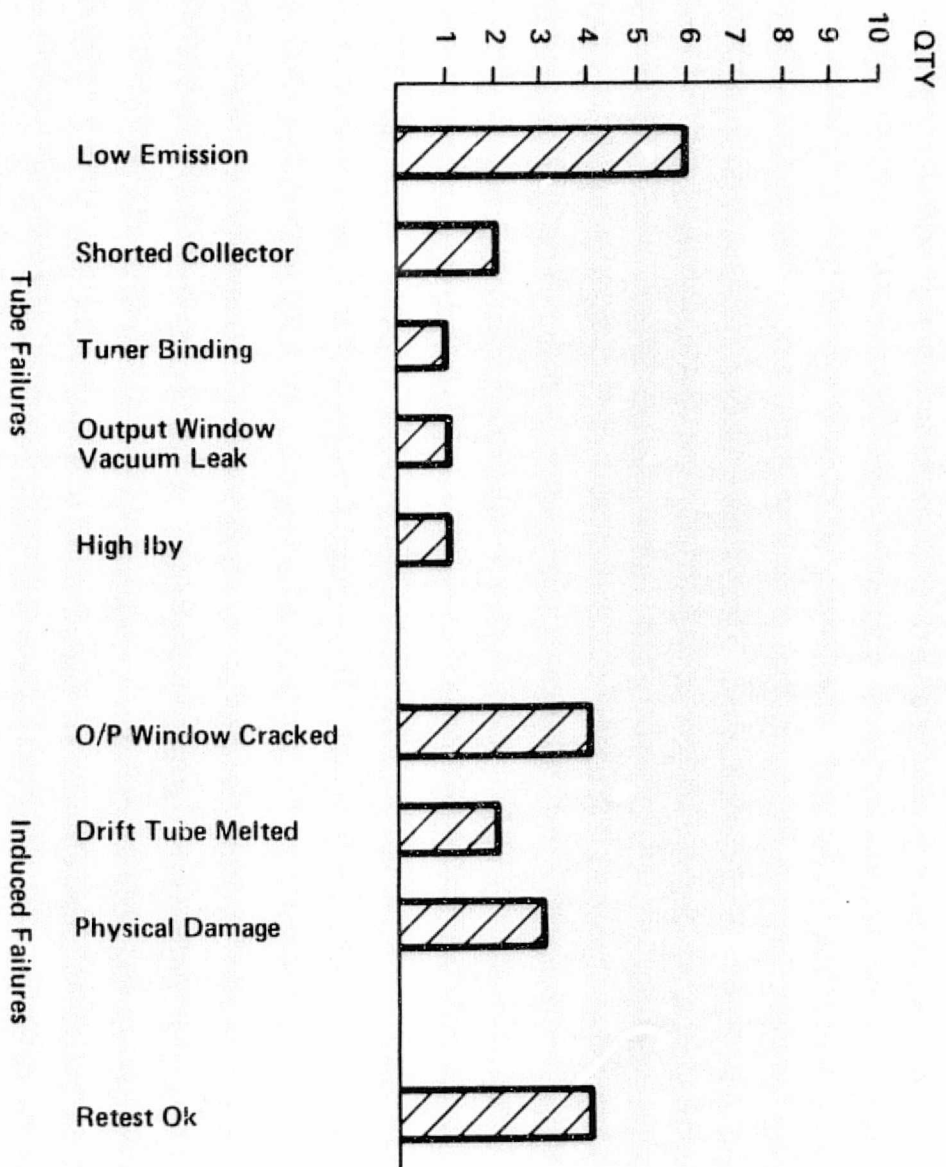


Figure 6-1. 5K70SG Failure Modes - 24 Tubes

Then, for eleven tubes,

$$MTBF = \frac{11 \times 14 \times 7 \times 8 \times 52}{11} = 40,768 \text{ hours.}$$

The tube failure rate per million hours is then

$$\frac{10^6}{MTBF} = \frac{10^6}{40,768} = 24.53$$

The predicted failure rate for various failure modes as applied to the major subassemblies of the klystron are shown in Table 6-1.

The predicted failure rate for an assembly is the product of the percentage failures of that assembly and the tube failure rate.

Example: Six cathode failures for eleven tubes

$$= \frac{6}{11} \times \frac{24.53}{1} = 13.38 \text{ failures}/10^6 \text{ hours.}$$

Figure 6-2 is a Weibull hazard plot of the probability of failure versus hours, based on the MTBF of 40,768 hours.

TABLE 6.1
FAILURE MODES AND PREDICTED FAILURE RATES*

Assembly	I Gun/Cathode	II Body	III Collector	IV Miscellaneous
Principal Failure Modes	1. No or low emission 2. Open or shorted heater	1. Erratic tuner 2. Binding tuner 3. Vacuum leaks 4. Braze defects	1. Shorted	1. Gas 2. Coolant leaks 3. Other
Predicted Failure Rate	13.38/10 ⁶ hrs	4.46/10 ⁶ hrs	4.46/10 ⁶ hrs	2.23/10 ⁶ hrs

* The predicted failure rate is the product of the percent failed for each assembly and the tube failure rate.

WEIBULL HAZARD
x 3 LOGARITHMIC CYCLES

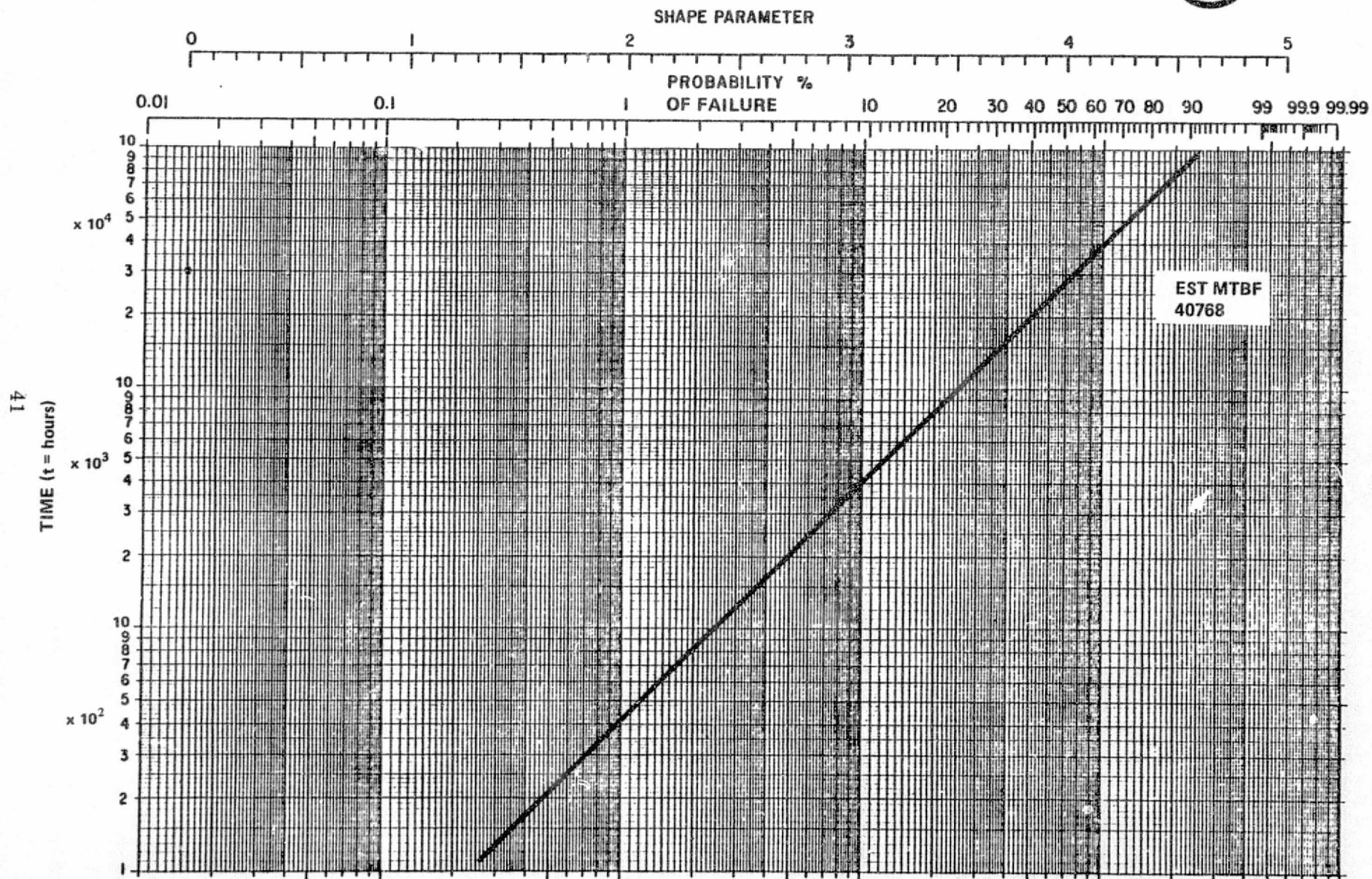
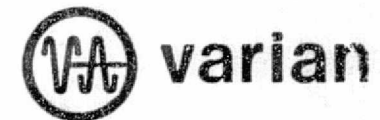


Figure 6-2. 5K70SK Estimated Tube Performance

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7. PRECAUTIONS TO INSURE RELIABILITY

7.1 UNCRATING INSTRUCTIONS FOR 5K70SK

Tools Required:

Klump or claw hammer
Screwdriver, power or standard
Lifting cables, web straps or ropes
Miscellaneous wrenches
Hoist

1. Remove the top cover of the outer box by removing all Klumps with a Klump or claw hammer.
2. Remove shockmount bolts (4 places) and remove the inner box by using two lifting cables, web straps, or ropes.
3. Tilt the inner box upright with the end marked "tube stand" down.
4. Remove all screws from the lid of the inner box and remove the lid. Remove the front half of the tube support inserts.

IMPORTANT: DISCONNECT VACION CABLE AT THE VACION PUMP LOCATED ON THE KLYSTRON WAVEGUIDE.

5. Remove the six (6) machine screws (circled) which hold the upper section of the inner box to the tube stand.
6. Carefully lift and remove the upper section of the inner box, avoiding contact with the klystron.
7. Attach lifting cable to lifting eyebolts on klystron, and draw cable just taut. Remove toe-clamps holding klystron to tube stand.
8. Lift klystron from tube stand.

For storage of the klystron, the uncrating procedure may be used in reverse order.

For VacIon pump monitoring during storage, the VacIon cable must be reconnected before the support inserts and the lid to the inner box are replaced.

7.2 INSTALLATION AND OPERATING PRECAUTIONS

7.2.1 Protective Measures

This tube should be used in equipment which provides protection as described below. In addition, installation and operating precautions should be observed, and ratings should not be exceeded.

High Voltage – Voltages required for operation of this tube are extremely dangerous to life; equipment should be designed with protective interlock circuits to make physical contact with these voltages impossible.

Microwave Radiation – Precautions should be taken to prevent exposure of personnel to the strong microwave fields generated by this tube. Microwave radiation due to leakage at the input coaxial connector and the output waveguide flange should be prevented by making tight rf input and output connections.

Heater Voltage – Heater voltage (7.5 V) should be applied for at least 5 minutes before applying beam voltage. Heater surge current should never exceed 24.0 A.

Beam Voltage – An overvoltage relay should be provided to limit the beam voltage to 22.0 kVdc. Interlocks should prevent the application of beam voltage before the heater has warmed up, coolants are flowing, and the focusing coil currents are applied.

Beam Current – An overcurrent relay should be provided to remove the beam voltage if the beam current exceeds 3.2 A.

Body Current – An overcurrent relay should be provided to remove the beam voltage if the tube body current exceeds 75 mAdc.

Focusing Field Protection - To prevent tube damage and maintain proper operation, rapid-acting undercurrent and overcurrent relays should be used in the focusing coil circuit. They should remove the beam voltage if the coil current either falls below 15 A or rises above 20 A. Tube failure can result within a few milliseconds if the focusing field fails while the beam voltage is applied, causing a large portion of the beam energy to be dissipated in a small area.

Cooling - The liquid cooling of the tube body and the electromagnet can be provided by water or by equal parts of water and ethylene glycol. Scaling and corrosion in the cooling system should be minimized by the use of metals close to copper in the galvanic series. Precautions should be taken to maintain the cleanliness of the cooling system, to minimize the dissolved oxygen of the coolant, and to operate at the lower inlet coolant temperature consistent with the operating temperature environment. Protective flow rate interlock circuits should be provided. Tube body and electromagnet cooling circuits can be connected in series for a common liquid flow rate of 1 gal/min. The maximum passband stability for the tube can be maintained if the coolant inlet temperature to the tube and electromagnet is controlled within $\pm 2^\circ \text{C}$, independently of seasonal, or day-to-night, ambient temperature changes. The maximum static pressure (blocked flow condition), for either tube or electromagnet, should never exceed 125 psig. Protective interlock devices should remove beam voltage if the coolant outlet temperature exceeds 80°C .

Reflected Power - The 5K70SK should not be used with load VSWRs greater than 1.5:1. Higher values of reflected power may damage the output window. Protection should be provided by installing a directional coupler between the tube and any transmission line components. If the VSWR exceeds 1.5:1, a rectified sample of reflected power should operate a circuit to remove rf drive from the tube within 10 msec. It is not necessary to remove beam voltage. Operation of the protective circuit should be checked regularly.

Arcs (In the Output Waveguide) - The output waveguide should be pressurized at 5 psig using either dry air or nitrogen if possible. If an arc-over should occur, a photoelectric arc detector near the tube output waveguide window should remove the rf drive within 10 μ sec after the start of the arc.

RF Leakage - External leakage should be prevented by making tight rf input and output connections. Under certain tuning conditions, regeneration or oscillation can occur if rf energy from the output line, or radiation from the antenna reaches the input cavity because of faulty rf connections or inadequate shielding.

7.2.2 Installation

Tube Handling - Sufficient care in handling the tube must be used to avoid bending any of the metal parts, or breaking any of the ceramic insulators, or the output waveguide window. More specifically, do not put any unsupported weight on the end of the output waveguide. Also, do not lift the tube by the output waveguide, the cathode assembly, or the lead wires. It is recommended that the tube be handled by the collector eyebolts.

Tube Inspection - Check the rf output window. No foreign particles of any kind should be between the silver-plated flange and the ceramic window. The ceramic window must be perfectly clean. If necessary, clean the window using acetone and a camel's-hair brush.

Coolant Connections - The collector hoses should not apply stress to the collector, which is attached to the tube by a ceramic insulator. The hose should be of insulating material to isolate the collector from ground electrically. Teflon-lined water hoses are recommended for the tube body and the electromagnet, to minimize coolant contamination.

Electrical Connections - If a dc heater supply is used to minimize heater hum, connect the common heater-cathode (black) lead to the positive side

of the heater supply. The heater supply should be insulated to withstand the full beam voltage. The rf output connector mates with a standard rectangular waveguide cover flange, UG-435A or equivalent.

1. Be sure waveguides are perfectly clean before attaching them to the tube.
2. Attach the waveguide to the tube. Align the mating flanges very carefully to avoid stress on the rf output window flange. Tighten screws evenly to prevent strain on the ceramic window. Waveguide should be pressurized to 5 psig with dry air or nitrogen if possible.

7.2.3 Operation

Preliminary Check - Check the following conditions before applying voltages to the tube.

1. Heater and cathode leads connected correctly.
2. Collector connected to supply correctly.
3. Tube body grounded.
4. Input coaxial connector and output waveguide flange connected into system.
5. Collector, body, and electromagnet coolants flowing.
6. Cathode cooling fan turned on.
7. RF drive at correct frequency.
8. Output waveguide pressurization at 5 psig.
9. VacIon pump connected.

Application of Voltage — Recommended operating voltages and currents are shown on the Test Performance Sheet which accompanies each tube. Prior to turn on, it is advisable to determine the internal gas pressure of the tube. Full high voltage should not be applied until the vacuum pressure is below 10^{-6} mm of Hg ($4 \mu\text{Ade}$). See Figure 7-1.

1. Turn on the electromagnet power supply and set the focusing current to the value shown on the Test Performance Sheet. Never allow the focusing current to drop below 16.5 A, when the tube is being operated.
2. Apply heater voltage. The heater current should be about 11.0 A after 5 minutes of warmup time. Surge current should never exceed 24.0 A.
3. Starting at zero, apply beam voltage gradually to voltage specified on Test Performance Sheet. Body current without drive should be less than 20 mA, with an absolute maximum of 75 mA.
4. Apply rf drive and adjust to obtain the desired output.

Removal of Voltages — All tube voltages may be removed simultaneously or in the reverse order from startup.

CAUTION: TO PROVIDE MAXIMUM RELIABILITY AND LONGEVITY, TUNING CYCLES SHOULD BE LIMITED TO AN ABSOLUTE MINIMUM. VACUUM BELLOWS LIFE IS DIRECTLY RELATED TO THE NUMBER OF TUNING CYCLES (see Section 3).

7.2.4 Transportation and storage

Use the packing case for transportation and storage of the tube when it is not in service.

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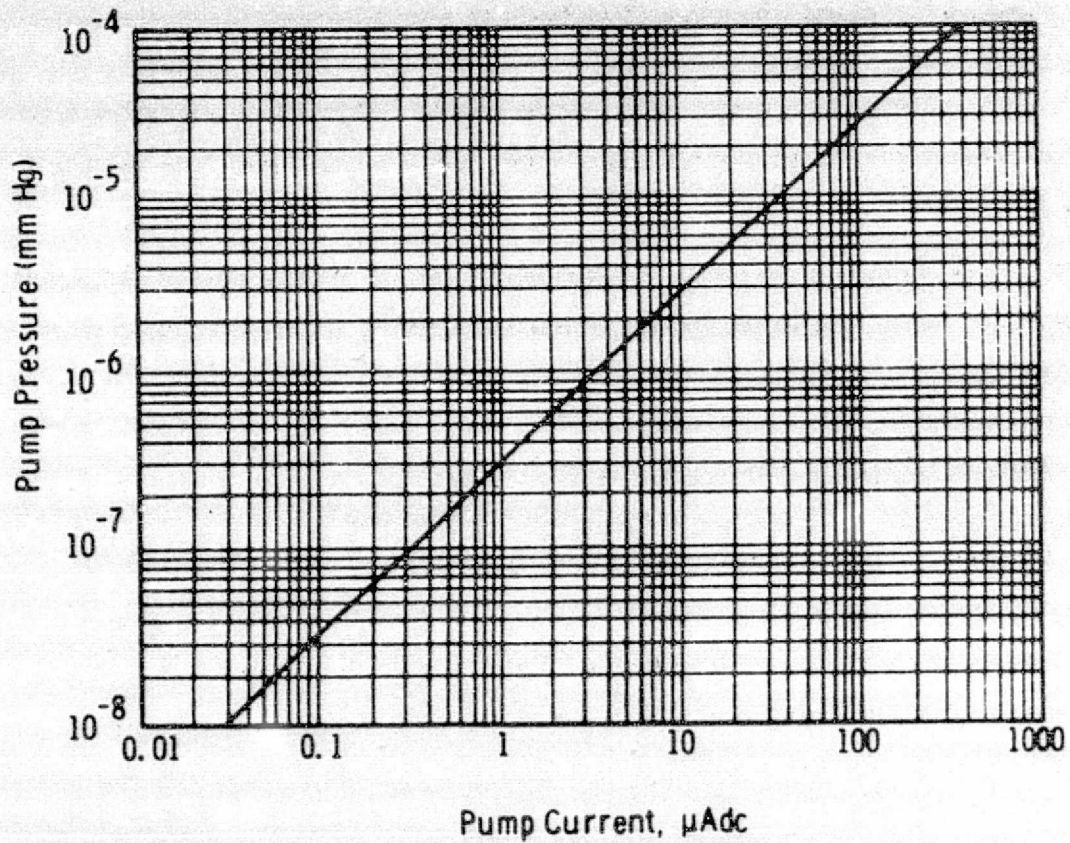


Figure 7-1. Vacuum Pressure vs Vac Ion Current

For storage below freezing, remove the coolant to avoid damaging the tube. Disconnect the water lines and attach mating parts to the tube body Hansen fittings. Drain the water from the tube and blow out the remaining coolant with warm, dry air. Remove the mating Hansen fittings.

The protective covers for the input connector and the output flange should be in place whenever the tube is in storage.

The gas pressure level can be checked at any time when the tube has been removed from its electromagnet and placed in storage. The VacIon pump permanent magnet must be in its correct position on the VacIon pump. Connect the VacIon pump cable to an appropriate power supply and put the pump into operation according to the instructions provided for the VacIon pump and its power supply.

7.3 RECOMMENDED FAILURE FORM FOR USERS

In order to insure continued reliability of field systems, it is vital to establish good communications between field personnel and factory engineers. Toward this goal, a recommended failure form is given as Figure 7-2. This form, filled out by the user and returned with the tube, could be instrumental in reduction of serious field problems.

Place X's in appropriate boxes

5K70SK Serial No.	Date Installed	Date Failed	Filament Hours	Radiate Hours	Filament Current		
					Hi	Low	Nml

Beam Current			Body Current			Hi Voltage Arcs		W.G. Arcs		Coolant Flow			Mechanical Problems	
Hi	Low	Nml	Hi	Low	Nml	Yes	No	Yes	No	Hi	Low	Nml	Yes	No

Antenna VSWR			Electro- magnet Current			Drive Power			Output Power			Vacuum Pressure	Noise Performance		Freq.
Hi	Low	Nml	Hi	Low	Nml	Hi	Low	Nml	Hi	Low	Nml	μ A	Nml	Poor	MHz

Site Location _____

System Serial No. _____

Number of Tuner Cycles _____

Describe the circumstances and/or sequence of events under which the product failed. Include remarks relating to installation problems, etc.

Figure 7-2. Recommended Failure Form

8. DESIGN VERIFICATION TESTS

Design Verification Test Plans for the 5K70SK-WBT klystron and for the remote step tuner Model 8191A are contained in the following pages.

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DESIGN VERIFICATION
TEST PLAN
VARIAN 5K70SK-WBT
with
6 CHANNEL AUTOMATIC TUNER

Division A
MAY 16, 1975

APPROVED:

NASA ENGINEERING

DATE

NASA QUALITY ASSURANCE

DATE

Art Goldfinger

VARIAN ENGINEERING

5/19/75

DATE

JE Robinson

VARIAN QUALITY ASSURANCE

5/19/75

DATE

TABLE OF CONTENTS

Revised 6/9/75

<u>Paragraph No.</u>	<u>Title</u>	<u>Page No.</u>
1.0	PURPOSE	1
2.0	EQUIPMENT REQUIREMENTS	1
2.1	Equipment Calibration	1
2.2	Equipment List.	2
2.3	CW Power Supply Meter Accuracies	4
3.0	APPLICABLE DOCUMENTS.	5
4.0	DESCRIPTION OF TESTS	5
4.1	Hydrostatic Pressure.	5
4.2	Body Coolant Pressure	5
4.3	Collector Coolant Pressure Drop	6
4.4	Heater Current.	6
4.5	Tuner Torque.	6
4.6	Focusing.	7
4.7	Beam Voltage.	7
4.8	Cathode Current	7
4.9	Emission.	8
4.10	Power Output	8
4.11	Bandwidth (dB).	9
4.12	Gain.	10
4.13	Efficiency	10
4.14	Warm-Up Time.	10
4.15	Body Current.	11
4.16	Amplitude Response.	11
4.17	Linearity	11
4.18	Interface	12
4.19	Spurious Outputs	13
4.20	Random Noise.	14
4.21	Tuning Curves	14
4.22	Output Power Stability.	14A

TABLE OF CONTENTS
(Cont'd)

Revised 6/9/75

<u>Paragraph No.</u>	<u>Title</u>	<u>Page No.</u>
5.0	TEST SYSTEM BLOCK DIAGRAMS	15
5.1	Power Output, Bandwidth, Efficiency and Gain	15
5.2	Linearity.	16
5.3	Spurious Outputs	17
6.0	TEST PERFORMANCE DATA SHEETS	18
6.1	Power Output, Bandwidth, Efficiency and Gain . .	18
6.2	Linearity Test	19
6.3	Warm-Up, Emission Tests.	20
6.4	Water Flow, Pressure Drop & Static Pressure Data	21
6.5	Tuner Torque	22
6.6	Tuning Curves	23
6.7	Random Noise	24
6.8	Spurious Output	25
6.9	Bandpass Curves.	26
6.9.1	Output Power Stability	27
6.9.2	Retrieved Bandpass Curves.	28
6.9.3	Thumbwheel and Zero Index Data	29

1.0

PURPOSE

This document defines the parameters and methods required to assess the performance of a five cavity 24 kW, CW klystron amplifier, tunable over the 2025 to 2120 MHz band with a remote controlled six position channel tuner. The acceptance tests are written to the requirements of NASA specification #73-15029.

The tests as delineated will not necessarily be performed in the order as presented in this document. A pre-requisite of performing acceptance testing is that sufficient preliminary testing has been accomplished to assess general tube performance.

During this preliminary test phase pre-set thumb wheel settings will be established that insure automatic channel selection by push button command. It is a requisite of acceptance testing that specification performance be met by push button command only.

Design Verification Tests will be performed on the first 5K70SK-WBT, with the understanding that one additional tube may be tested to the DVT plan at the request of the government.

2.0

EQUIPMENT REQUIREMENTS

The test equipment given in Paragraph 2.2, or its equivalent, will be used in the acceptance testing of the 5K70SK-WBT and push button controlled six position channel tuner.

2.1 Equipment Calibration

The calibrations and control of the test equipment will be performed by Instrument Services under the direction of Quality Assurance. Controls and procedures for calibration are specified by Quality Assurance Operating procedure 87-800-154 and Instrument Services Operating Manual 87-800-153.

2.2 Equipment List

ID No.	Description	Manufacturer	Type Or Model	Frequency of Calibration	Percent Accuracy
1	Sweep Oscillator	Hewlett-Packard	692B	N/A	
2	Microwave Amplifier	Hewlett-Packard	491C	N/A	
3	Low Pass Filter	Microlab/FXR	LA-30N	N/A	
4	Variable Attenuator	Narda	792FF	N/A	
5	Frequency Meter	Hewlett-Packard	536A	1 year	± 0.05
6	Dual-Directional Coupler	Hewlett-Packard	767D	1 year	± 1.0
7	Isolator	Sperry	D-44S5	N/A	
8	Thermistor	Hewlett-Packard	478A	N/A	
9	Power Meter	Hewlett-Packard	431C	3 mo.	± 5.0 FS
10	3 Port Rf Sampler	Varian	Special	N/A	
11	Water Load	Eimac	WL-204	N/A	
12	Thermometer Set	Varian	Special	1 year	± 1.0
13	Low Pass Filter	Microlab/FXR	LA-30N	N/A	
14	Variable Attenuator	Narda	791FM	N/A	
15	Spectrum Analyzer	Hewlett-Packard	3555	3 mo.	± 3.0
16	Oscilloscope Camera	Hewlett-Packard	197A	N/A	
17	Low Pass Filter	Microlab/FXR	LA-30N	N/A	
18	Variable Attenuator	Narda	792FF	N/A	
19	Thermistor	Hewlett-Packard	478A	N/A	
20	Power Meter	Hewlett-Packard	431C	3 mo.	± 5.0 FS
21	Low Pass Filter	Microlab/FXR	LA-30N	N/A	
22	10 dB Attenuator	Weinschel	530-10	N/A	
23	Crystal Detector	Hewlett-Packard	420A	N/A	
24	Oscilloscope	Tektronix	545A	3 mo.	± 3.0
25	Collector Flow Meter	Fisher and Porter	0-40 gpm	3 mo.	± 2.0 FS
26	Body Flow Meter	Fisher and Porter	0-4 gpm	3 mo.	± 2.0 FS

2.2 Equipment List (cont'd)

<u>ID No.</u>	<u>Description</u>	<u>Manufacturer</u>	<u>Type Or Model</u>	<u>Frequency of Calibration</u>	<u>Percent Accuracy</u>
27	Pressure Gauge	J. P. Marsh	0-100 psi	3 mo.	± 2.0 FS
28	Focusing Magnet	Varian	H-193	N/A	
29	Heater-Magnet-H.V. Power Supply	Eimac	11919	3 mo.	± 2.0 FS (See meter accuracy list)
30	Pressure Fixture	Varian	0-300 psi	3 mo.	± 2.0 FS
31	Torque Wrench	Waters	940-2	3 mo.	± 5.0 FS
32	Signal Generator	Rhode & Schwartz	SLRD	N/A	
33	Directional Coupler	Narda	3043-10	N/A	
34	Water Load Flow Meter	Fisher and Porter	0-14 gpm	3 mo.	± 2.0 FS
35	S-Band TWT	Varian	VTS-6050	N/A	
36	Preselector	Hewlett-Packard	8445A	N/A	
37	W/G to Coax Adapter	Narda	615	N/A	
38	30 db attenuator	Weinshel	210-30	3 mo	± 0.1db

2.3 Meter Accuracies for Power Supply No. 11919

<u>NAME</u>	<u>MANUFACTURER</u>	<u>TYPE OR MODEL</u>	<u>RANGE</u>	<u>PERCENT ACCURACY</u>
Heater Voltage	Westinghouse	DY-2	0-15 Vac	± 2.0 FS
Heater Current	Westinghouse	DY-2	0-50 Aac	± 2.0 FS
Beam Voltage	Westinghouse	DX	0-25 kVdc	± 1.0 FS
Body Current	Assembly Products	461	0-500 mAdc	± 2.0 FS
Beam Current	Weston	301	0-3 Adc	± 1.0 FS
Magnet Current	Opad Electric	0-25	Adc	± 2.0 FS

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3.0 APPLICABLE DOCUMENTS

NAS-5-20601

NASA Technical Specification #73-15029

Palo Alto Tube Division Quality Assurance Operating
Procedure Manual

Technical Manual S-Band Klystron Power Amplifier Subsystem
Model 11-076

4.0 DESCRIPTION OF TESTS

4.1 Test: Hydrostatic Pressure

Procedure: Fill the body and collector coolant lines
with coolant and pressurize to 125 psi.

RECORD OBSERVATIONS

Verification: There shall be no evidence of coolant
leakage.

4.2 Test: Body Coolant Pressure Drop

Procedure: Connect a differential pressure gauge across
the body coolant lines. Set the flow rate at
1.2 gpm and read the pressure drop.

RECORD PRESSURE DROP

Verification: The pressure drop shall not exceed 65 psi.

4.3 Test: Collector Coolant Pressure Drop

Procedure: Connect a differential pressure gauge across the collector coolant lines. Set the flow rate at 18.5 gpm and read the pressure drop.

RECORD PRESSURE DROP

Verification: The pressure drop shall not exceed 40 psi.

4.4 Test: Heater Current

Procedure: Apply heater voltage and adjust to 7.5 volts. The surge current should not exceed 24 amperes. After five minutes, read the heater current.

RECORD HEATER CURRENT

Verification: The heater current shall not fall below 9.5 amperes nor exceed 13.0 amperes.

4.5 Test: Tuner Torque

Procedure: Tune each cavity over its specified range (see tuning curves) using a 0-100 inch-ounce torque wrench tool. Observe the maximum torque encountered.

RECORD MAXIMUM TORQUE

Verification: The torque required to tune the tube shall not exceed 80-inch-ounces.

4.6 Test: Focusing

Procedure: The klystron shall be electromagnetically focused by the H-193 electromagnet assembly. The voltage source shall not exceed 200 volts. The optimum value shall be determined during preliminary testing. This optimum value will be used throughout the series of tests.

RECORD FOCUS VOLTAGE AND CURRENT

Verification: The focus current shall not exceed 25 amperes.

4.7 Test: Beam Voltage

Procedure: Apply heater voltage as per Paragraph 4.4. Apply voltage to the electromagnet assembly and adjust to specified value. Apply beam voltage and adjust to specified value.

RECORD BEAM VOLTAGE

Verification: The beam voltage shall not exceed 22.0 kV.

4.8 Test: Cathode Current

Procedure: Operate the klystron as per paragraph 4.7. Allow 5 minutes for the current to stabilize.

RECORD CATHODE CURRENT

Verification: The cathode current shall not exceed
2.78 Adc.

4.9 Test: Emission

Procedure: Operate klystron as per Paragraph 4.7 for 15 minutes, after which the heater voltage shall be reduced to 6.75 volts. After 15 minutes of stabilization at the reduced heater voltage, the beam current shall be measured.

RECORD CHANGE IN BEAM CURRENT

Verification: The change in beam current shall not exceed 200 mA.

4.10 Test: Power Output

Procedure:

- Step 1 Connect equipment as shown in Figure 5.1 and operate per Paragraph 4.7.
- Step 2 Actuate tuning mechanism to achieve tuning for Channel 1.
- Step 3 Increase rf drive and observe output response with crystal detector.
- Step 4 Switch sweep selector to manual.
- Step 5 Adjust rf drive power level and rf drive frequency to achieve rated power output at point of maximum power output.
- Step 6 Set recorder Y-axis drive level.
- Step 7 Set sweep time to ten seconds.
- Step 8 Record drive levels to 0 dB and -1.0 dB and leave attenuator set for 0 dB level.
- Step 9 Disconnect Y-axis of recorder from drive power bridge and connect to output power bridge.

- Step 10 Set sweep selector to manual and adjust frequency to point of highest power output.
- Step 11 Observe water load temperature differential and calculate power output.
- Step 12 Record power output.
- Step 13 Adjust output attenuator to produce a point on the recorder Y axis to coincide with the 0 dB line drawn in Step 8.

Verification: The power output shall not be less than 24 kW measured on the highest point within the specified bandwidth.

- Step 14 Record output trace.
- Step 15 Calibrate the X axis using frequency meter and manual sweep.
- Step 16 Repeat Steps 2 through 5 with reduced drive to obtain data at the 12 kW and 1.2 kW level.
- Step 17 Repeat Steps 2 through 16 for Channels 2 through 6.

4.11 Test: Bandwidth (1 dB)

Procedure: From graphs obtained in Paragraph 4.10 determine 1 dB bandwidth.

RECORD BANDWIDTH

Verification: The bandwidth measured at the 1 dB point shall not fall below 20 MHz.

RECORD ALL PRE SET THUMB WHEEL SETTINGS
FOR SIX CHANNEL OPERATION

4.12 Test: Gain

Procedure: While operating as per Paragraph 4.10, compute the rf gain (10 x log power out/drive).

RECORD GAIN

Verification: This gain shall not fall below 45 dB at the 24 kW level. No more than 750 milliwatts will be required within the 24 kW to 1.2 kW range.

4.13 Test: Efficiency

Procedure: While operating as per Paragraph 4.10, compute the efficiency:

$$\frac{\text{rf power output}}{\text{dc power input}}$$

RECORD EFFICIENCY

Verification: The efficiency shall not fall below 37% at the 24 kW level.
The efficiency shall not fall below 17% at the 12 kW level.
The efficiency shall not fall below 1.5% at the 1.2 kW level.

4.14 Test: Warm-Up Time

Procedure: Operate klystron as per Paragraph 4.11, allowing a maximum of 5 minutes heater warm-up.

OBSERVE POWER OUTPUT

Verification: The tube shall produce rated output power.

4.15 Test: Body Current

Procedure: Observe klystron as per Paragraph 4.10 and observe body current.

RECORD BODY CURRENT

Verification: The body current shall not exceed 75 mAdc.

4.16 Test: Amplitude Response

Procedure: From graphs obtained in Paragraph 4.10 determine the maximum amplitude variation over center 20 MHz of bandpass.

RECORD AMPLITUDE VARIATION

Verification: The tube amplitude response shall not vary more than ± 0.5 dB, (1.0 dB peak-to-peak) over the center 20 MHz of the bandpass.

4.17 Test: Linearity

Procedure: With the klystron tuned to Channel 3 and operating as per Paragraph 4.10, apply drive signals of 2064.25 MHz and 2065.75 MHz such that the power output for each frequency is 2.0 kW. Measure the third order inter-modulation products on the spectrum analyzer.

RECORD INTERMODULATION PRODUCTS

Verification: The third order intermodulation products shall not be less than 30 dB below the 2.0 kW level.

NOTE: On one selected channel, the 5K70SK-WBT will be required to demonstrate specification performance with input line and output load VSWR's equal to, but no better than 1.1 to 1.0.

4.18 Test: Interface

Procedure: The klystron shall be mechanically interchangeable with the 5K70SG excepting the getter, which will be replaced by a Varian VacIon pump.

OBSERVE INTERCHANGEABILITY

4.18 Test: Interface

Verification: All electrical connections, waveguides, coaxial jacks coolant fittings, etc. shall interface identically with the 5K70SG excepting the getter which will be replaced by a Varian VacIon pump.

4.19 Test: Spurious Outputs

Procedure: Setup equipment as shown in diagrams 5.1 and 5.3.

The klystron will be operating on Channel 3 with a center frequency of 2065 MHz.

- 1) With a minimum of 30 db attenuator set in precision attenuator apply sample of R.F. signal from T.U.T.
- 2) Adjust spectrum analyzer display for 10MHz/Div scan width (100MHz full scan) 300 KHz I.F. bandwidth
Sweep rate - any convenient rate to maintain calibrated display.
- 3) Tune spectrum analyzer to output frequency of T.U.T. and adjust analyzer attenuator controls to place top of response on 0 db reference line of display.
- 4) Retune spectrum analyzer for center frequency of 2250MHz (100MHz full scan).
- 5) Remove 30 db precision attenuator.
(reference line now corresponds to -30 db below carrier signal).
- 6) Observe spectrum analyzer display for any signals greater than -85 db below carrier.

RECORD SPURIOUS OUTPUTS

Verification: Spurious signals in the 2200 - 2300 MHz range shall be less than -85 db carrier.

4.20 Test: Random Noise

Procedure: While operating as per Paragraph 4.10 and tuned to Channel 3, a portion of the rf output will be sampled as a dc reference representing 24 kW. This dc level will appear as a straight horizontal line on the oscilloscope. When switched to ac coupling and increased sensitivity, the scope will exhibit a trace configuration mainly determined by the ripple of the power supply. The ac components riding on this ripple will display random noise frequencies which when compared in amplitude to the original dc voltage representing 24 kW will yield a random noise figure. (20 log voltage_{dc} / voltage_{ac}.)

RECORD RANDOM NOISE

Verification: The random noise shall be at least 60 dB down from 24 kW.

4.21 Test: Tuning Curves

Procedure: Operate the klystron as per Paragraph 4.10, except beam voltage shall be 10 kVdc. Apply swept drive of 10 mW or less and synchronously tune the tube with unsaturated drive over the specified frequency range. Observe each cavity's number of turns from the low frequency stop.

RECORD CAVITY TURNS

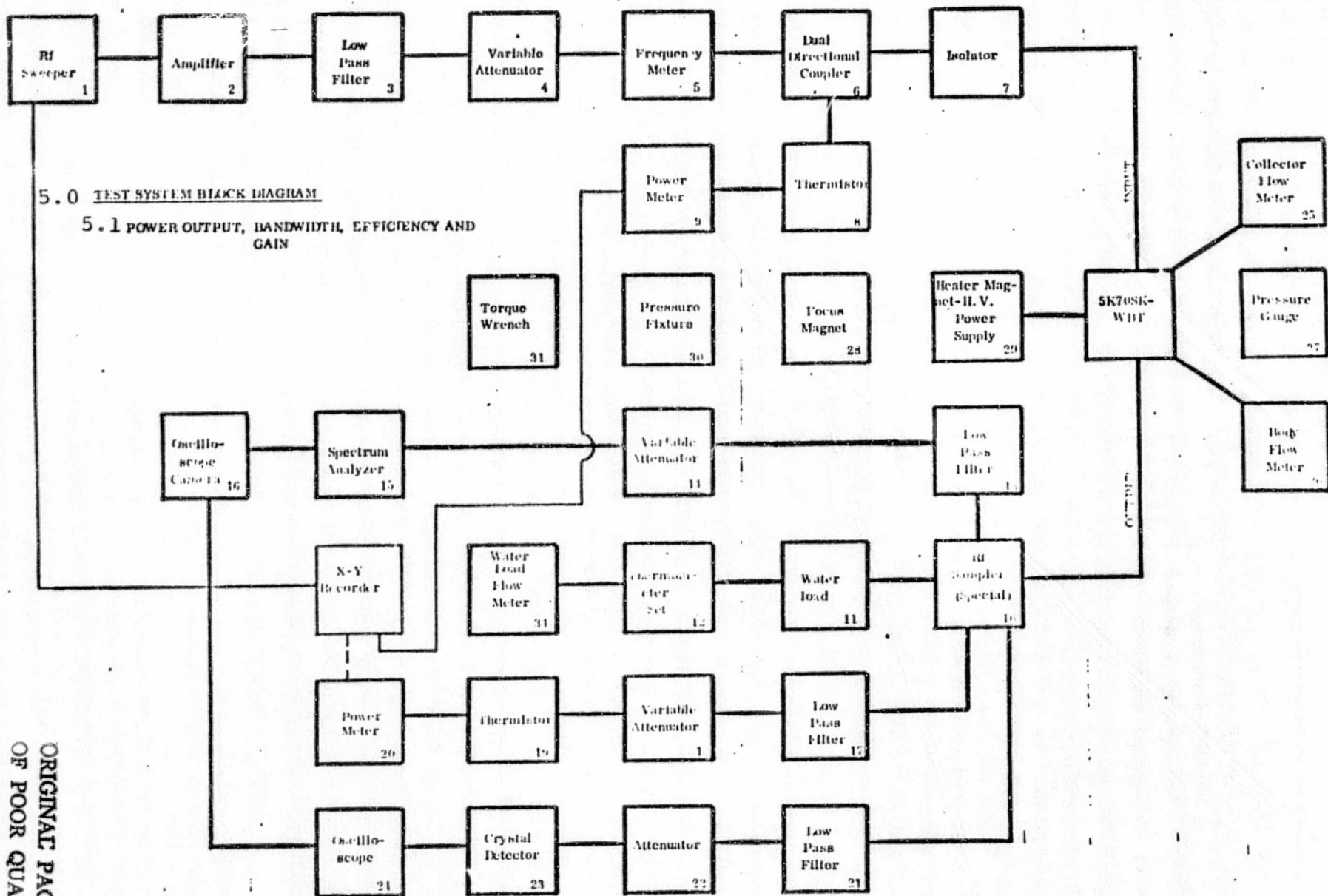
Verification: A tuning curve shall be given for each cavity starting from the low frequency stop.

4.22 Test: Output Power Stability

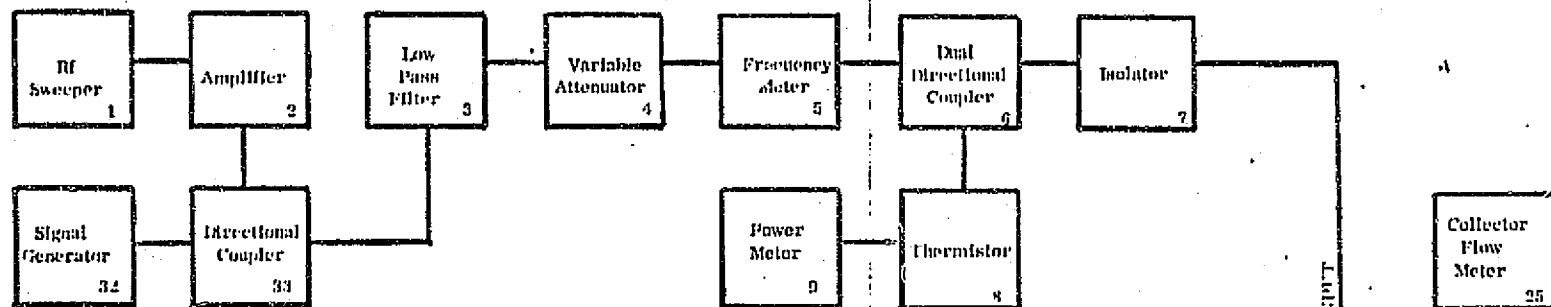
Procedure: While operating as per Paragraph 4.10 but with a minimum warm-up and stabilization time of 20 minutes, a power stability run of at least 8 hours will be initiated. At 2-hour intervals, all input parameters to the klystron will be adjusted to those values established at the initiation of the test.

RECORD POWER OUTPUT AT 2-HOUR INTERVALS.

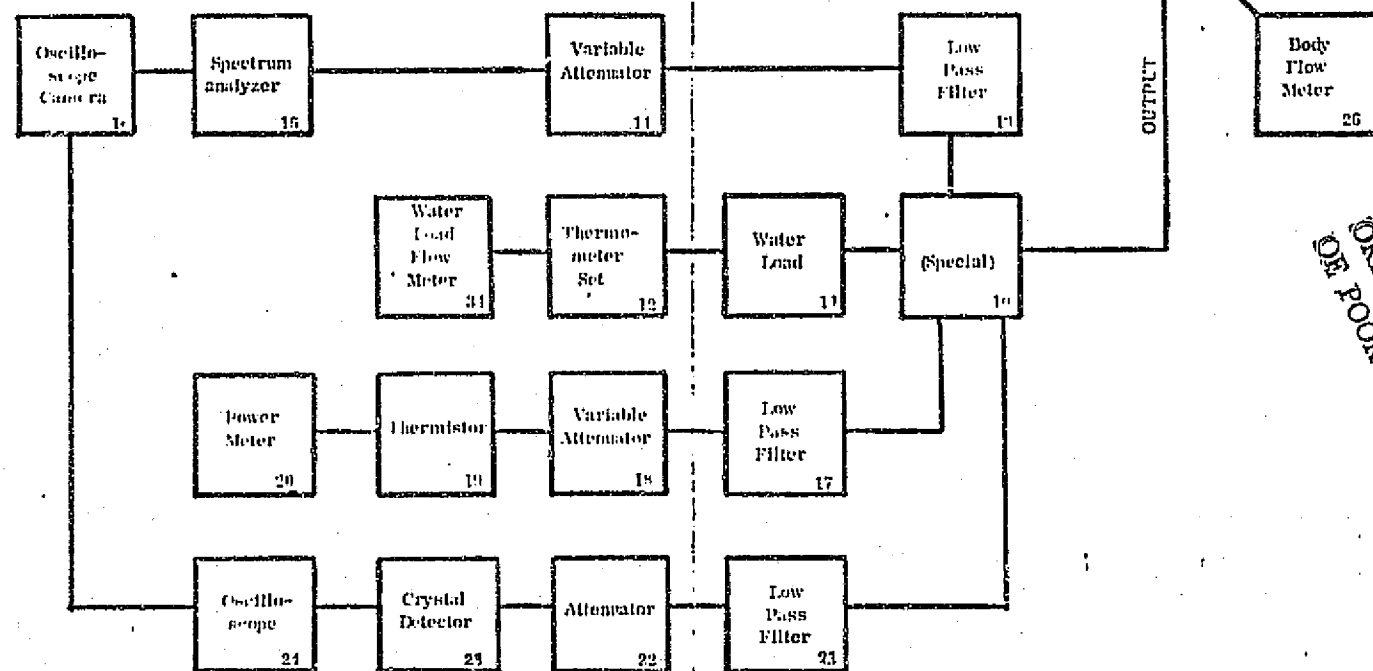
Verification: Power output does not vary more than $\pm 0.2\text{dB}$ over an eight-hour period.



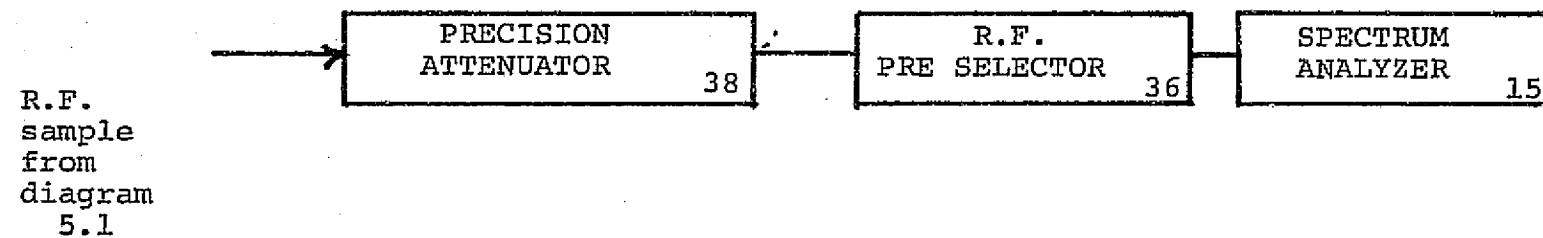
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5.0 TEST SYSTEM BLOCK DIAGRAM
5.2 LINEARITY



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5.0 TEST SYSTEM BLOCK DIAGRAM

5.3 Spurious Output

Channel No. 1

Parameter	Symbol	24 kw		12 kw		1.2 kw		UNITS
		Min	Max	Min	Max	Min	Max	
Frequency	F:	<u>2035</u>	-----	<u>2035</u>	-----	<u>2035</u>	-----	MHz
Beam Voltage	Eb:	<u>22</u>	----- 22.0	<u>22</u>	----- 22.0	<u>22</u>	----- 22.0	kVdc
Beam Current	Ib:	<u>2.6</u>	----- 2.78	<u>2.6</u>	----- 2.78	<u>2.6</u>	----- 2.78	Adc
Power Output	Po:	<u>24</u>	24.0 -----	<u>12</u>	12.0 -----	<u>1.2</u>	1.2 -----	kW
Rf Input Power	Pd:	<u>540</u>	----- 750	<u>161</u>	----- 750	<u>12.5</u>	----- 750	mW
Efficiency	Eff:	<u>41.9</u>	37.0 -----	<u>21.0</u>	17.0 -----	<u>2.1</u>	1.5 -----	%
Gain	Gain:	<u>46.5</u>	45 -----	<u>48.7</u>	45 -----	<u>49.8</u>	45 -----	dB
Body Current	Iby:	<u>29</u>	----- 75	<u>19</u>	----- 75	<u>11</u>	----- 75	mAdc
Bandwidth	Bw:	<u>23.8</u>	20 -----	<u>25</u>	20 -----	<u>25</u>	20 -----	MHz
Heater Voltage	Ef:	<u>7.5</u>	----- 7.5	<u>7.5</u>	----- 7.5	<u>7.5</u>	----- 7.5	Vac
Heater Current	If:	<u>10.6</u>	----- 13.0	<u>10.6</u>	----- 13.0	<u>10.6</u>	----- 13.0	Aac
Magnet Current	Im:	<u>16</u>	----- 25.0	<u>16</u>	----- 25.0	<u>16</u>	----- 25.0	Aac
Amplitude Response	G:	<u><±0.5</u>	----- ±0.5	<u><±0.5</u>	----- ±0.5	<u><±0.5</u>	----- ±0.5	dB

Tested By W BOWER Date JUNE 2, 1975Varian QAR Ron Jensen Date 6/2/75Customer QAR Howard Hingman Date 6/4/75

Cavity Settings

A 221B 195C 196D 211E 179

6.0 TEST PERFORMANCE DATA SHEETS

6.1 Power Output, Bandwidth, Efficiency and Gain

Channel No. 2

Parameter	Symbol	24 kw		12 kw		1.2 kw		UNI
		Min	Max	Min	Max	Min	Max	
Frequency	F:	<u>2050</u>	----	<u>2050</u>	----	<u>2050</u>	----	MHz
Beam Voltage	Eb:	<u>22</u>	22.0	<u>22</u>	22.0	<u>22</u>	22.0	kVd
Beam Current	Ib:	<u>2.6</u>	2.78	<u>2.6</u>	2.78	<u>2.6</u>	2.78	Ade
Power Output	Po:	<u>24</u>	24.0	<u>12</u>	12.0	<u>1.2</u>	1.2	kW
Rf Input Power	Pd:	<u>342</u>	750	<u>105</u>	750	<u>8.7</u>	750	mW
Efficiency	Eff:	<u>41.9</u>	37.0	<u>21.0</u>	17.0	<u>2.1</u>	1.5	%
Gain	Gain:	<u>48.5</u>	45	<u>50.6</u>	45	<u>51.4</u>	45	dB
Body Current	Iby:	<u>25</u>	75	<u>13</u>	75	<u>13</u>	75	mA
Bandwidth	Bw:	<u>23</u>	20	<u>24</u>	20	<u>23.5</u>	20	MHz
Heater Voltage	Ef:	<u>7.5</u>	7.5	<u>7.5</u>	7.5	<u>7.5</u>	7.5	Vac
Heater Current	If:	<u>10.6</u>	13.0	<u>10.6</u>	13.0	<u>10.6</u>	13.0	A ac
Magnet Current	Im:	<u>16</u>	25.0	<u>16</u>	25.0	<u>16</u>	25.0	Ade
Amplitude Response	G:	<u>±0.5</u>	±0.5	<u>±0.5</u>	±0.5	<u>±0.5</u>	±0.5	dB

Tested By W BOWERDate JUNE 2, 1975Varian QAR Ron JensenDate 6/2/75Customer QAR Howard KingmanDate 6/4/75

Cavity Settings

A 311B 231C 295D 338E 271

6.0 TEST PERFORMANCE DATA SHEETS

6.1 Power Output, Bandwidth, Efficiency and Gain

Channel No. 3

Parameter	Symbol	24 kw		12 kw		1.2 kw		UNI
		Min	Max	Min	Max	Min	Max	
Frequency	F:	<u>2065</u>	----	<u>2065</u>	----	<u>2065</u>	----	MHz
Beam Voltage	Eb:	<u>22</u>	---- 22.0	<u>22</u>	---- 22.0	<u>22</u>	---- 22.0	kVd
Beam Current	Ib:	<u>2.6</u>	---- 2.78	<u>2.6</u>	---- 2.78	<u>2.6</u>	---- 2.78	Adc
Power Output	Po:	<u>24</u>	24.0 ----	<u>12</u>	12.0 ----	<u>1.2</u>	1.2 ----	kW
Rf Input Power	Pd:	<u>335</u>	---- 750	<u>100</u>	---- 750	<u>6.8</u>	--- 750	mW
Efficiency	Eff:	<u>41.9</u>	37.0 ----	<u>21.0</u>	17.0 ----	<u>2.1</u>	1.5 ----	%
Gain	Gain:	<u>48.6</u>	45 ----	<u>50.8</u>	45 ----	<u>52.5</u>	45 ----	dB
Body Current	Iby:	<u>30</u>	---- 75	<u>16</u>	---- 75	<u>12</u>	---- 75	mA
Bandwidth	Bw:	<u>22.5</u>	20 ----	<u>22.5</u>	20 ----	<u>2.8</u>	20 ----	MHz
Heater Voltage	Eh:	<u>7.5</u>	---- 7.5	<u>7.5</u>	---- 7.5	<u>7.5</u>	---- 7.5	Vac
Heater Current	If:	<u>10.6</u>	---- 13.0	<u>10.6</u>	---- 13.0	<u>10.6</u>	---- 13.0	Aac
Magnet Current	Im:	<u>16</u>	---- 25.0	<u>16</u>	---- 25.0	<u>16</u>	---- 25.0	Adc
Amplitude Response	G:	<u><±0.5</u>	---- ±0.5	<u><±0.5</u>	---- ±0.5	<u><±0.5</u>	---- ±0.5	dB

Tested By W BOWER
 Varian QAR Ron Jensen
 Customer QAR Howard Higgins

Date JUNE 2, 1975
 Date 6/2/75
 Date 6/4/75

Cavity Settings

A 391
 B 316
 C 401
 D 460
 E 381

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6.0 TEST PERFORMANCE DATA SHEETS

6.1 Power Output, Bandwidth, Efficiency and Gain

Channel No. 4

Parameter	Symbol	24 kw		12 kw		1.2 kw		UN1
		Min	Max	Min	Max	Min	Max	
Frequency	F:	<u>2080</u>	----	<u>2080</u>	----	<u>2080</u>	----	MHz
Beam Voltage	Eb:	<u>22</u>	22.0	<u>22</u>	22.0	<u>22</u>	22.0	kVd
Beam Current	Ib:	<u>2.6</u>	2.78	<u>2.6</u>	2.78	<u>2.6</u>	2.78	Adc
Power Output	Po:	<u>24</u>	24.0	<u>12</u>	12.0	<u>1.2</u>	1.2	kW
RF Input Power	Pd:	<u>320</u>	750	<u>95</u>	750	<u>6.5</u>	750	mW
Efficiency	Erf:	<u>41.9</u>	37.0	<u>21.0</u>	17.0	<u>2.1</u>	1.5	%
Gain	Gain:	<u>48.8</u>	45	<u>51.0</u>	45	<u>52.7</u>	45	dB
Beam Current	Iby:	<u>40</u>	75	<u>20</u>	75	<u>12</u>	75	uAd
Bandwidth	BW:	<u>21.5</u>	20	<u>21.7</u>	20	<u>22.5</u>	20	MHz
Heater Voltage	Ef:	<u>7.5</u>	7.5	<u>7.5</u>	7.5	<u>7.5</u>	7.5	V
Heater Current	If:	<u>10.6</u>	13.0	<u>10.6</u>	13.0	<u>10.6</u>	13.0	A
Magnet Current	Im:	<u>16</u>	25.0	<u>16</u>	25.0	<u>16</u>	25.0	A
Amplitude Response	G:	<u><±0.5</u>	±0.5	<u><±0.5</u>	±0.5	<u><±0.5</u>	±0.5	dB

Tested By W BOWERDate JUNE 3, 1975

Cavity Settings

A 460

Variation QAR

Ron JensenDate 6/3/75B 423

Customer QAR

Howard KingmanDate 6/4/75C 497D 570E 484

6.0 TEST PERFORMANCE DATA SHEETS

6.1 Power Output, Bandwidth, Efficiency and Gain

Channel No. 5

Parameter	Symbol	24 kw		12 kw		1.2 kw		UNIT
		Min	Max	Min	Max	Min	Max	
Frequency	F:	<u>2095</u>	----	<u>2095</u>	----	<u>2095</u>	----	MHz
Beam Voltage	Eb:	<u>22</u>	---- 22.0	<u>22</u>	---- 22.0	<u>22</u>	---- 22.0	kVd
Beam Current	Ib:	<u>2.6</u>	---- 2.78	<u>2.6</u>	---- 2.78	<u>2.6</u>	---- 2.78	Adc
Power Output	Po:	<u>24</u>	24.0 ----	<u>12</u>	12.0 ----	<u>1.2</u>	1.2 ----	kW
Rf Input Power	Pd:	<u>220</u>	---- 750	<u>74</u>	---- 750	<u>5.5</u>	--- 750	mW
Efficiency	Eff:	<u>41.9</u>	37.0 ----	<u>21.0</u>	17.0 ----	<u>2.1</u>	1.5 ----	%
Gain	Gain:	<u>50.4</u>	45 ----	<u>52.1</u>	45 ----	<u>53.4</u>	45 ----	dB
Body Current	Iby:	<u>35</u>	---- 75	<u>19</u>	---- 75	<u>12</u>	---- 75	mA
Bandwidth	Bw:	<u>22.6</u>	20 ----	<u>22.8</u>	20 ----	<u>22.5</u>	20 ----	MHz
Heater Voltage	Ef:	<u>7.5</u>	---- 7.5	<u>7.5</u>	---- 7.5	<u>7.5</u>	---- 7.5	Vac
Heater Current	If:	<u>10.6</u>	---- 13.0	<u>10.6</u>	---- 13.0	<u>10.6</u>	---- 13.0	Aac
Magnet Current	Im:	<u>16</u>	---- 25.0	<u>16</u>	---- 25.0	<u>16</u>	---- 25.0	Adc
Amplitude Response	G:	<u><±0.5</u>	---- ±0.5	<u><±0.5</u>	---- ±0.5	<u><±0.5</u>	---- ±0.5	dB

Tested By W BOWERDate JUNE 3, 1975

Cavity Settings

Varian QAR

Roy JensenDate 6/3/75

Customer QAR

Howard J. RuzmanDate 6/4/75A 520B 453C 580D 663E 568ORIGINAL PAGE 13
OF 1000 SLIDES

6.0 TEST PERFORMANCE DATA SHEETS

6.1 Power Output, Bandwidth, Efficiency
and Gain

Channel No. 6

Parameter	Symbol	24 kw		12 kw		1.2 kw		UNI
		Min	Max	Min	Max	Min	Max	
Frequency	F:	<u>2110</u>	-----	<u>2110</u>	-----	<u>2110</u>	-----	MHz
Beam Voltage	Eb:	<u>22</u>	----- 22.0	<u>22</u>	----- 22.0	<u>22</u>	----- 22.0	kVd
Beam Current	Ib:	<u>2.6</u>	----- 2.78	<u>2.6</u>	----- 2.78	<u>2.6</u>	----- 2.78	Ade
Power Output	Po:	<u>24</u>	24.0 -----	<u>12</u>	12.0 -----	<u>1.2</u>	1.2 -----	W
Reflector Power	Pd:	<u>420</u>	----- 750	<u>126</u>	----- 750	<u>8.7</u>	----- 750	mW
Efficiency	E _{eff} :	<u>41.9</u>	37.0 -----	<u>21.0</u>	17.0 -----	<u>2.1</u>	1.5 -----	%
Gain	Gain:	<u>47.6</u>	45 -----	<u>49.8</u>	45 -----	<u>51.4</u>	45 -----	dB
Beam Current	I _{Ly} :	<u>32</u>	----- 75	<u>15</u>	----- 75	<u>14</u>	----- 75	uAd
Bandwidth	Bw:	<u>22</u>	20 -----	<u>22</u>	20 -----	<u>22</u>	20 -----	Hz
Beam Voltage	E _f :	<u>7.5</u>	----- 7.5	<u>7.5</u>	----- 7.5	<u>7.5</u>	----- 7.5	Vac
Beam Current	I _f :	<u>10.6</u>	----- 13.0	<u>10.6</u>	----- 13.0	<u>10.6</u>	----- 13.0	Aac
Magnet Current	I _m :	<u>16</u>	----- 25.0	<u>16</u>	----- 25.0	<u>16</u>	----- 25.0	Ade
Amplitude Response	G:	<u>±0.5</u>	----- ±0.5	<u>±0.5</u>	----- ±0.5	<u>±0.5</u>	----- ±0.5	dB

Tested By W BOWLERDate JUNE 3, 1975

Cavity Settings

Variation QAR Ron JensenDate 6/3/75A 592Customer QAR Howard KuymanDate 6/4/75B 620C 663D 754 *758E 656

6.0 TEST PERFORMANCE DATA SHEETS

6.1 Power Output, Bandwidth, Efficiency and Gain

* changed 6/4/75 out of spec.
OKAY AT 758

ORIGINAL PAGE IS
OF POOR QUALITY

LINEARITY TEST

<u>PARAMETERS</u>		<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
Center Frequency	F_0 : <u>2065</u>			
Frequency Separation	F_{sep} : <u>1.5</u>	---	---	MHz
Frequency (1)	F_1 : <u>$F_0 + 0.75$</u>	---	---	MHz
Power Output (F_1)	PO_{F1} : <u>2.0</u>	---	---	kW
Frequency (2)	F_2 : <u>$F_0 - 0.75$</u>	---	---	MHz
Power Output (F_2)	PO_{F2} : <u>2.0</u>	---	---	kW
3rd Order Intermodulation	IM_3 : <u>-34 + -35</u>	-30	---	dB

Tested By

Varian QAR

Customer QAR

Art Goldfinger

Ron Jensen

Harold Kujawa

DATE

6/3/75

DATE

6/3/75

DATE

6/3/75

6.0 TEST PERFORMANCE DATA SHEET

6.2 Linearity

5K703K-WBT S/N
KLYSTRON

2

WARM-UP, EMISSION AND TUNABILITY TESTS

<u>PARAMETER</u>	<u>SYMBOL</u>		<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
Warm-Up Time 5 minutes	Po	<u>okay</u>	24.0	----	kW

Comments:

Emission	A Ib	<u>10</u>	----	200	mAdc
----------	------	-----------	------	-----	------

Comments:

Tested By

Art Goldfinger

Varian DAR

Ron Jensen

Customer DAR

Howard Kujawa

DATE

6/4/75

DATE

6/4/75

DATE

6/4/75

6.0 TEST PERFORMANCE DATA SHEET

6.3 Warm-Up and Emission Tests

- 20 -

ORIGINAL PAGE IS
OF POOR QUALITY

WATER FLOW, PRESSURE DROP AND STATIC PRESSURE DATA

<u>PARAMETER</u>	<u>SYMBOL</u>		<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
------------------	---------------	--	-------------	-------------	--------------

COLLECTOR

Flow	Flow:	<u>18.5</u>	---	---	gpm
Pressure Drop	ΔP :	<u>30.5</u>	---	40	psi

BODY

Flow	Flow:	<u>1.2</u>	---	---	gpm
Pressure Drop	ΔP :	<u>20.0</u>	---	65	psi

STATIC PRESSURE

125 psig	----	<u>No LEAKAGE</u>	No Leakage
----------	------	-------------------	------------

Tested By W BOWER
 Varian QAR R. Jensen
 Customer QAR Howard Kingman

DATE MAY 29, 1975
 DATE 6/4/75
 DATE 6/4/75

6.0 TEST PERFORMANCE DATA SHEET

6.4 Water flow, pressure drop and Static
pressure data

TUNER TORQUE TEST

<u>PARAMETER</u>	<u>SYMBOL</u>	<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
Torque	Tq	---	30	in.oz
Cavity A				<u>73</u>
Cavity B				<u>62</u>
Cavity C				<u>45</u>
Cavity D				<u>64</u>
Cavity E				<u>75</u>

Tested By W BOWER

Varian QAR Ron Jensen 

Customer QAR Howard Kingman

DATE 6-6-75

DATE 6/6/75

DATE 6/6/75 -

6.0 TEST PERFORMANCE DATA SHEET

6.5 Tuner Torque

5K70SK-WBT

TUNING CURVE ORIGINAL PAGE 18
OF POOR QUALITY

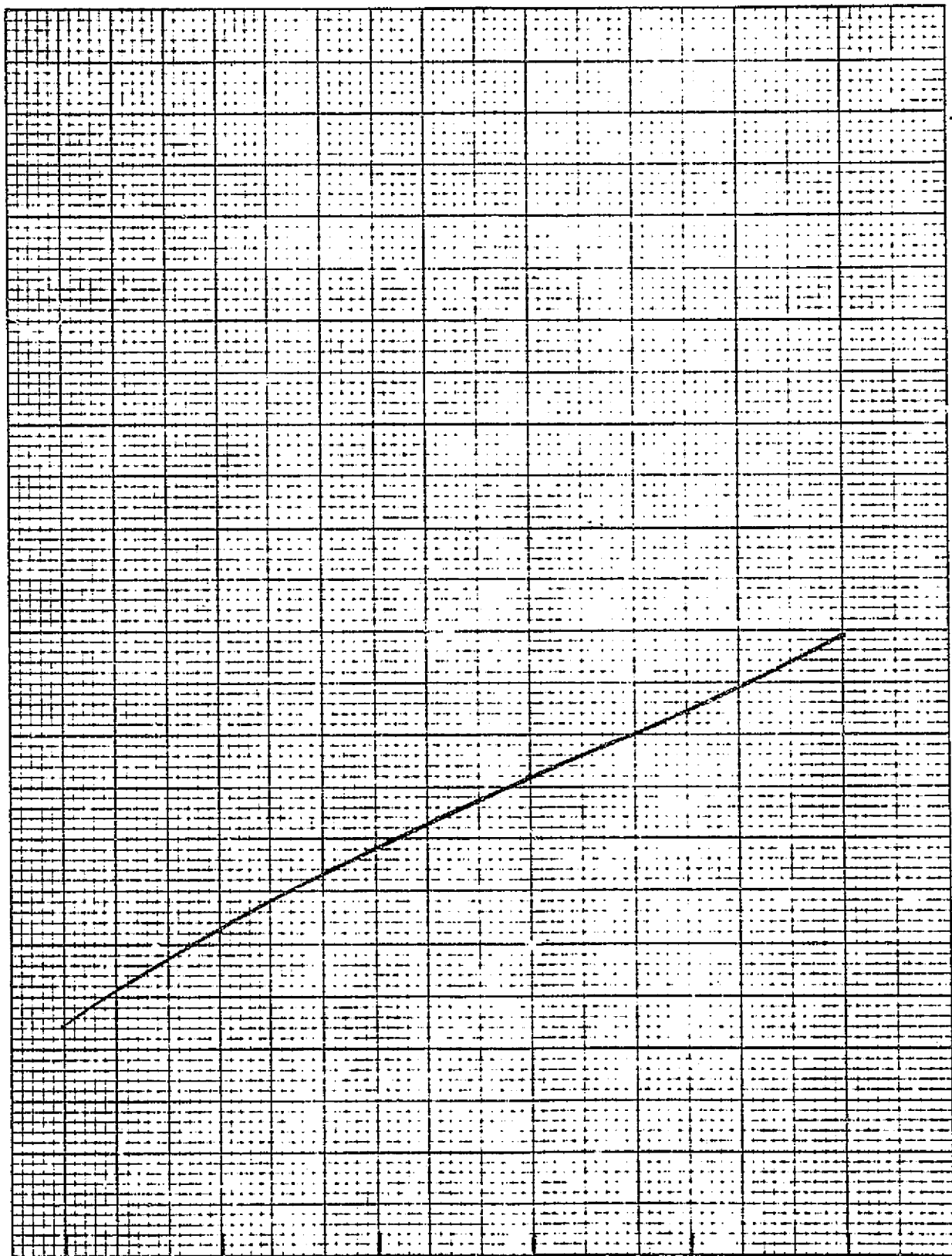
Serial # 2

Date 6-5-75

CAVITY A

THUMBWHEEL - VEEDER ROOT SETTINGS

1000
900
800
700
600
500
400
300
200
100



Ch.1 Ch.2 Ch.3 Ch.4 Ch.5 Ch.6
2035 2050 2065 2080 2095 2110

6.0 TEST PERFORMANCE DATA SHEET

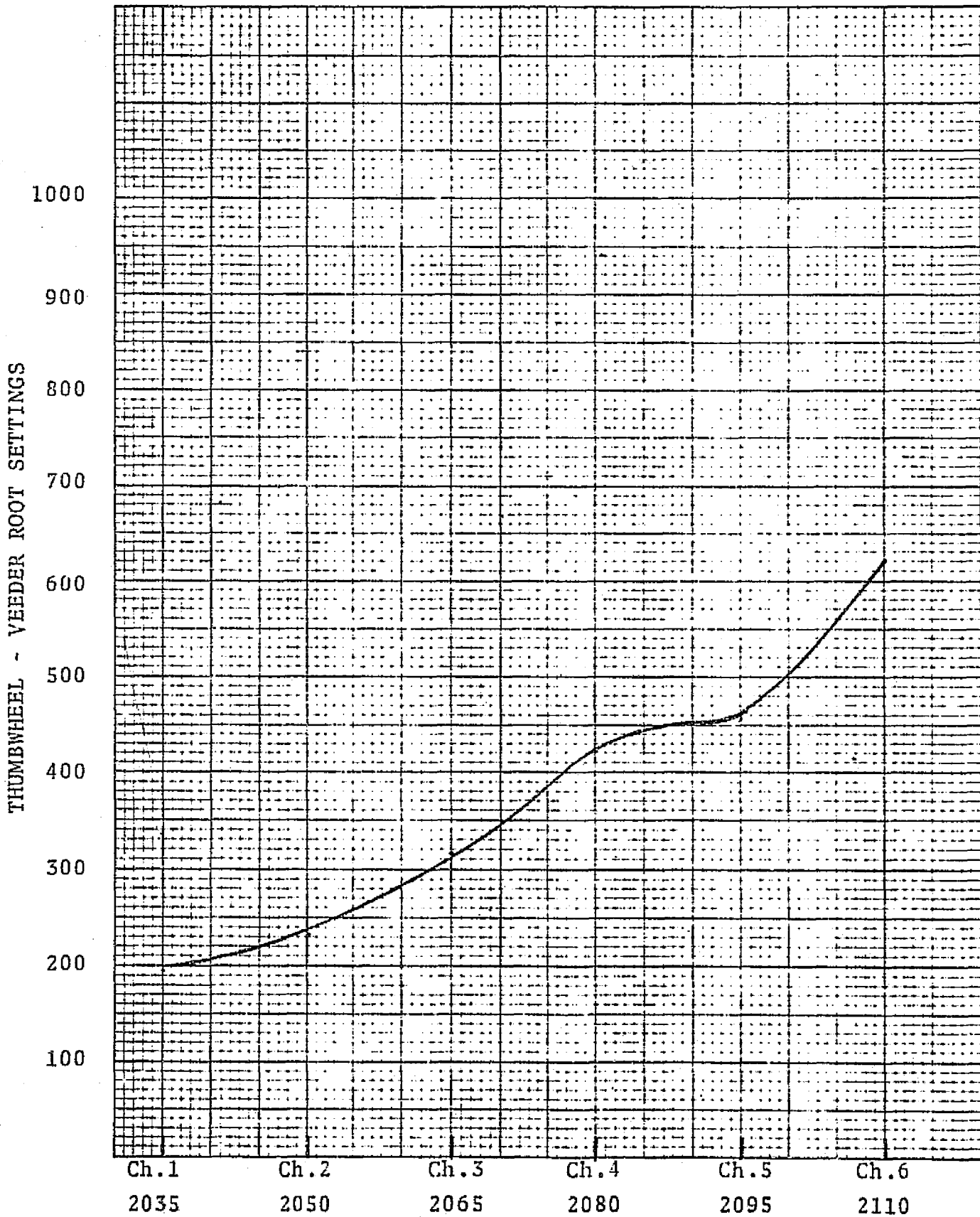
FREQUENCY MHz

6.6 Tuning Curves

5K70SK-WBT
TUNING CURVES

Serial # 2
Date 6-5-75

CAVITY B



6.0 TEST PERFORMANCE DATA SHEET

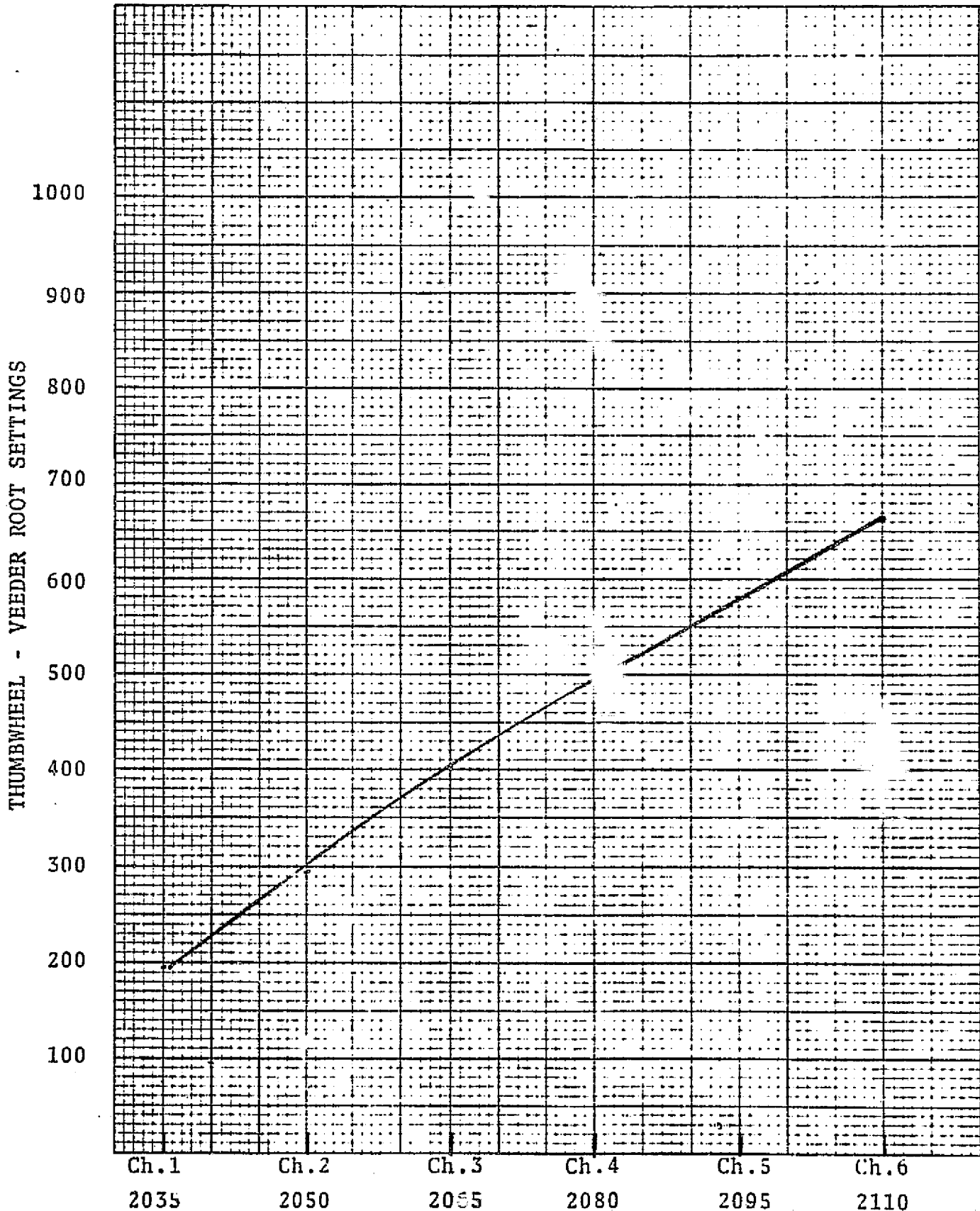
6.6 Tuning Curves

5K70SK-WBT
TUNING CURVES

Serial # 2
Date 6-5-75

CAVITY C

ORIGINAL PAGE 13
OF POOR QUALITY



6.0 TEST PERFORMANCE DATA SHEET

6.6 Tuning Curves

FREQUENCY MHz

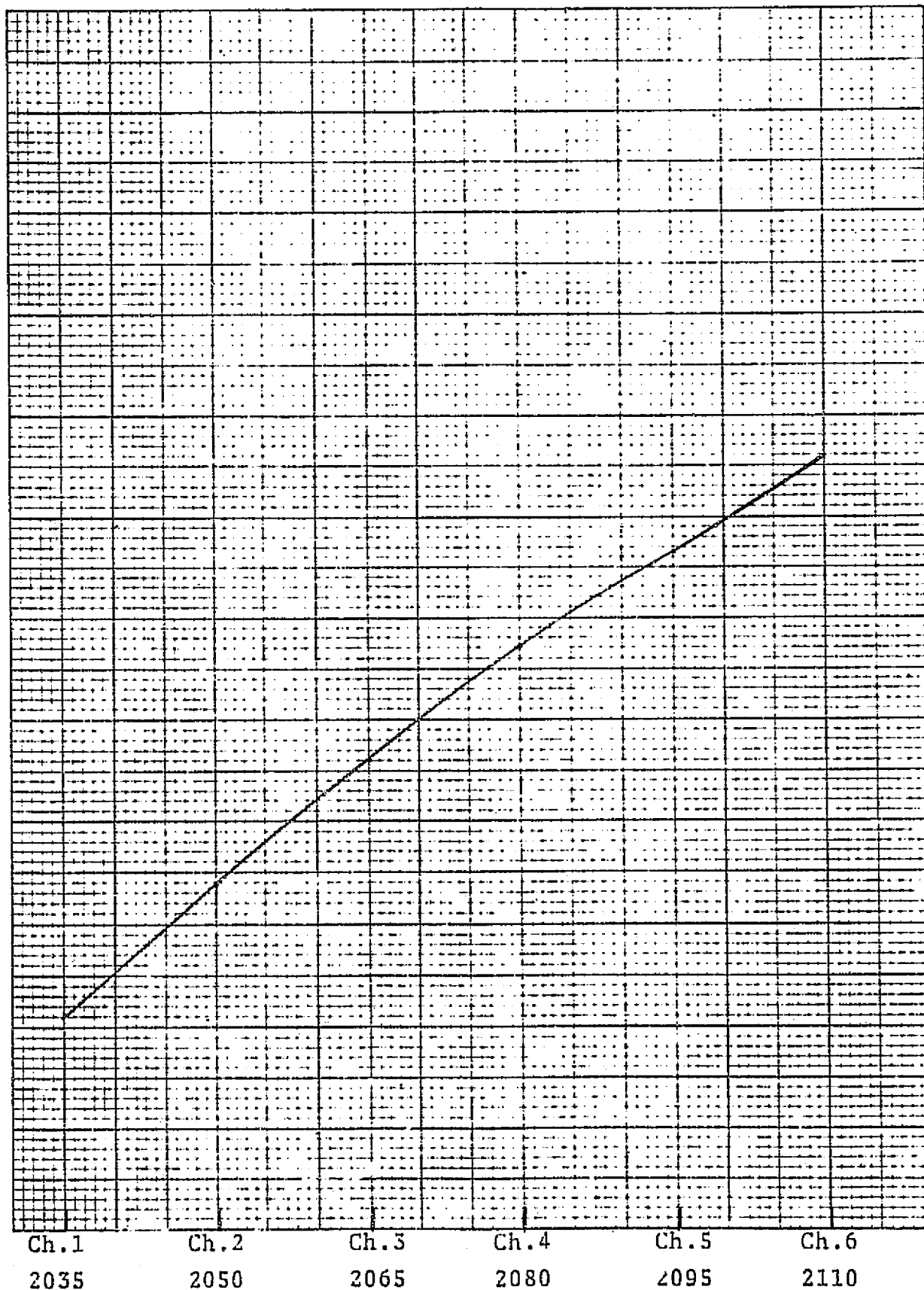
5K70SK-WBT
TUNING CURVES

Serial # 2
Date 6-5-75

CAVITY 0

THUMBWHEEL - VEEDER ROOT SETTINGS

1000
900
800
700
600
500
400
300
200
100



6.0 TEST PERFORMANCE DATA SHEET

FREQUENCY MHz

6.6 Tuning Curves

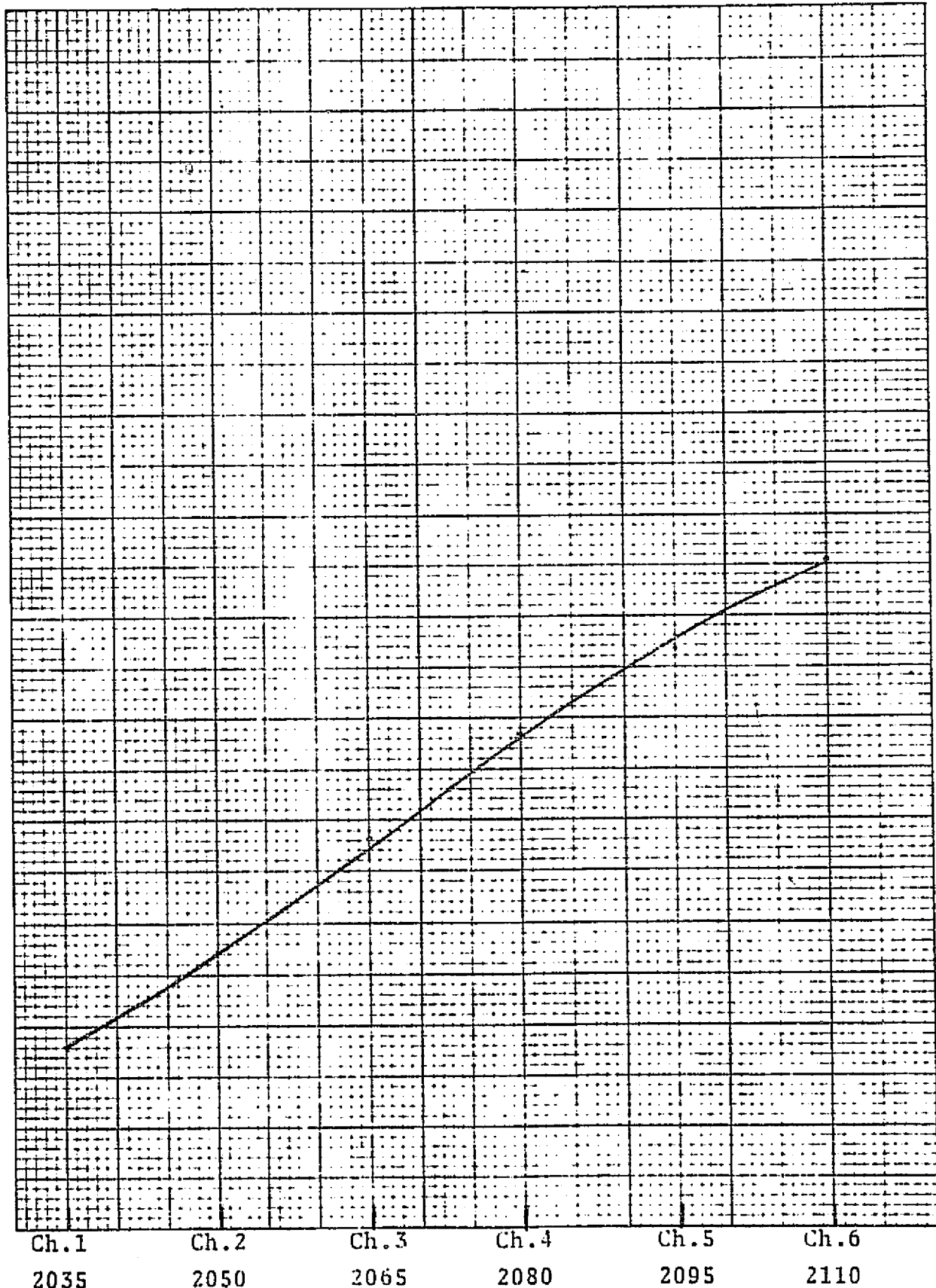
5K70SK-WBT
TUNING CURVES

Serial # 2
Date 6-5-75

CAVITY E

THUMBWHEEL - VEEDER ROOT SETTINGS

1000
900
800
700
600
500
400
300
200
100



6.0 TEST PERFORMANCE DATA SHEET

FREQUENCY MHz

6.6 Tuning Curves

5K70SK-WBT S/N 2
KLYSTRON

RANDOM NOISE TEST

<u>PARAMETER</u>	<u>SYMBOL</u>		<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
Frequency	F:	<u>2065</u>			
Power Output	Po:	<u>24.0</u>	24.0	---	kW
Random Noise	Nr:	<u><-60</u>	---	-60	dB

Tested By Art Folsfinger
Varian QAR Ranzen 
Customer QAR Howard Kingman

DATE 6/3/75
DATE 6/3/75
DATE 6/3/75

SPURIOUS OUTPUT TEST

<u>PARAMETER</u>	<u>SYMBOL</u>	<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
Frequency	F:			
Power Output	Po:			
Spurious Output	NF:			

Tested By

Art Goldfinger

Varian QAR

Ron Johnson

Customer QAR

Harold Kijon

DATE

6/3/75

DATE

6/3/75

DATE

6/3/75

6.0 TEST PERFORMANCE DATA SHEET

6.8 Spurious Output

5K765K-UBT SERIAL NO. 2

CHANNEL 1

DATE: 6-2-75 BY: U.R.B

FILAMENT VOLTAGE 7.5 V

BEAM VOLTAGE 22 kV

POWER OUTPUT 1.2 kW

FILAMENT CURRENT 10.6 A

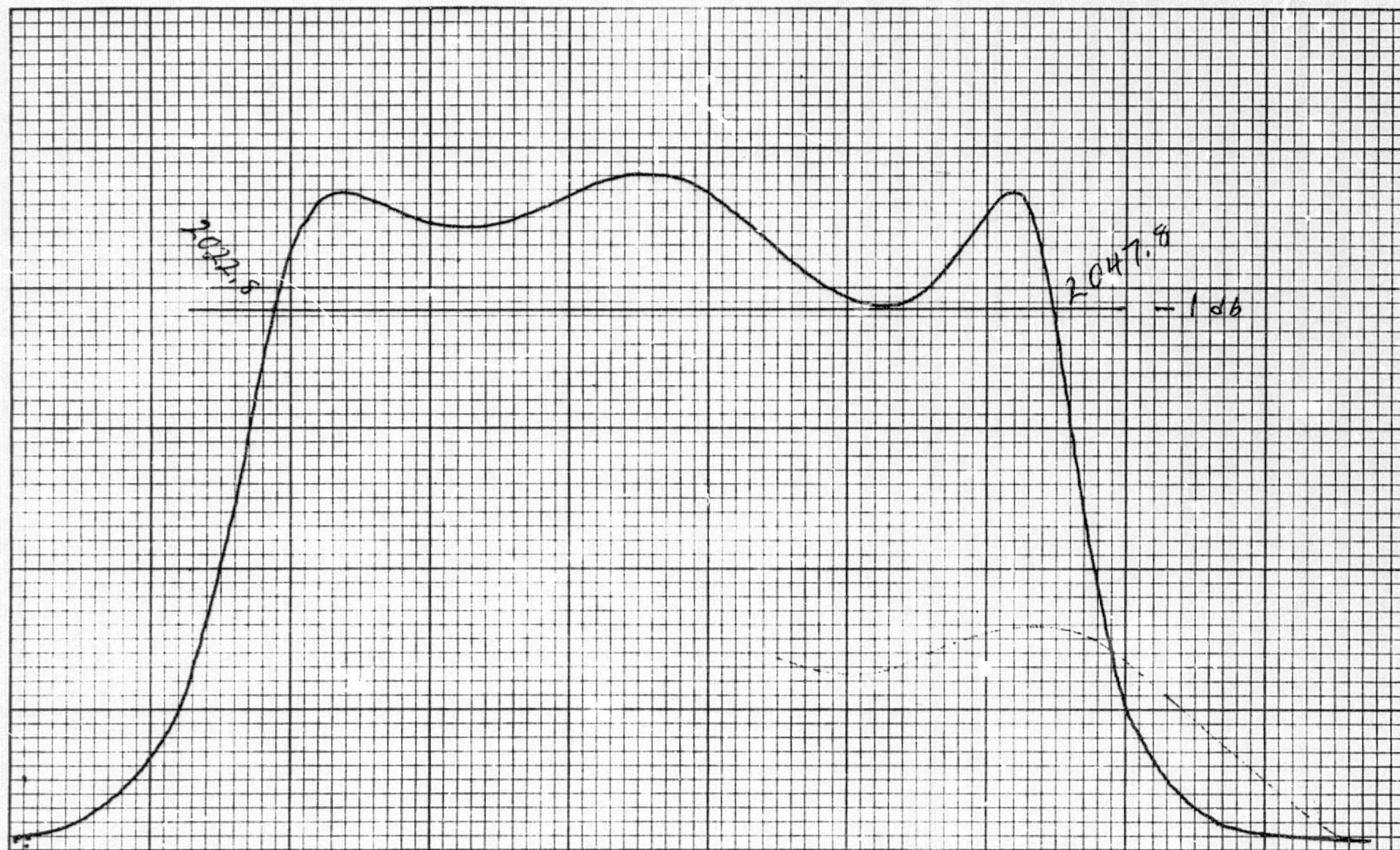
BEAM CURRENT 2.6 A

DRIVE POWER 12.5 mW

MAGNET CURRENT 16 A

BODY CURRENT 11 mA

GAIN 49.8 dB



FREQUENCY MHz

5K705K-WBT SERIAL NO. 2

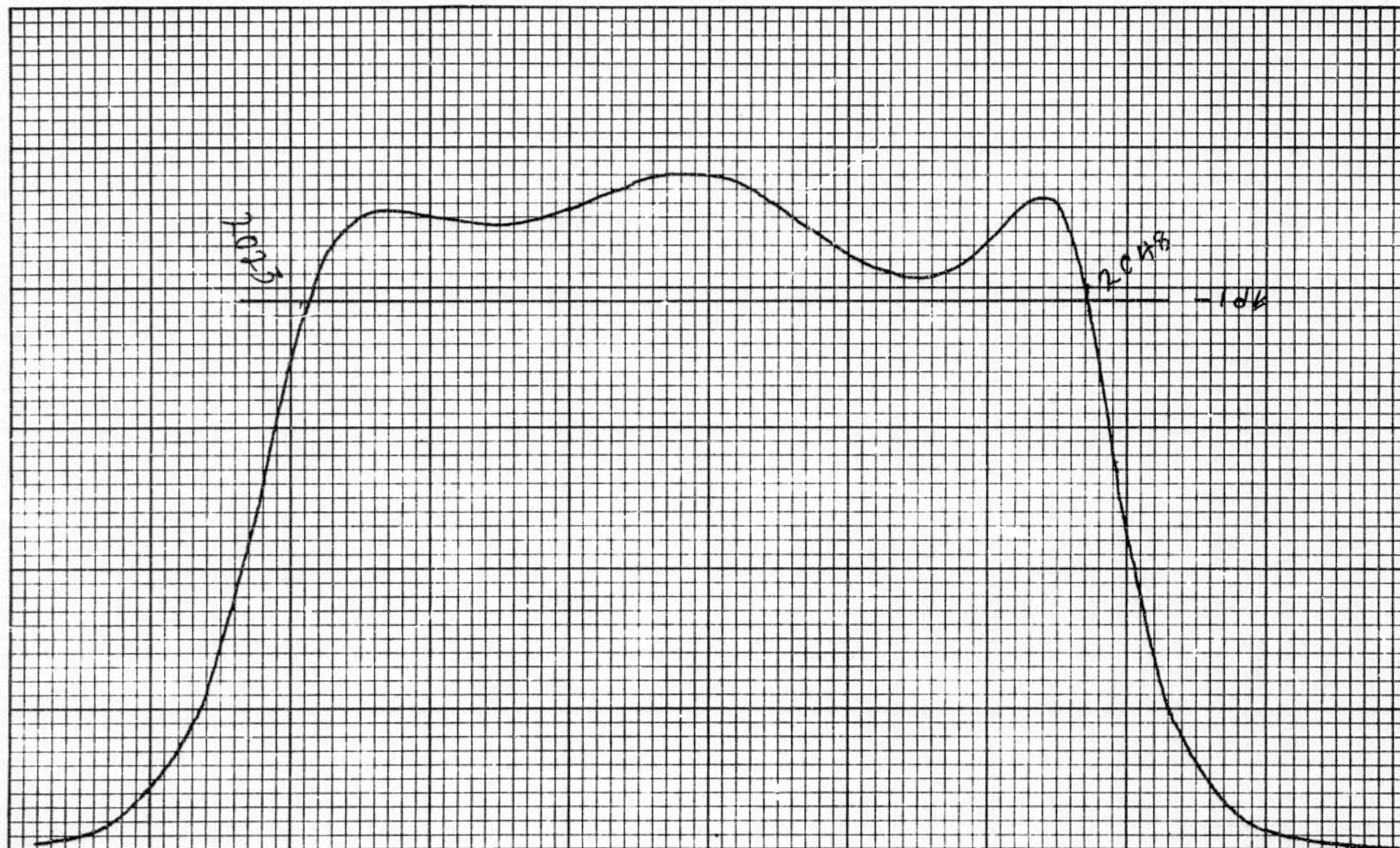
CHANNEL 1

DATE: 6-2-75 BY: W/RD

FILAMENT VOLTAGE 7.5 V
FILAMENT CURRENT 10.6 A
MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV
BEAM CURRENT 2.6 A
BODY CURRENT 19 mA

POWER OUTPUT 12 kW
DRIVE POWER 16.1 mW
GAIN 48.7 dB



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OF POOR QUALITY

5K7CSK-WBT SERIAL NO. 2

CHANNEL 1

DATE: 6-2-75 BY: WRB

FILAMENT VOLTAGE 7.5 V

BEAM VOLTAGE 22 kV

POWER OUTPUT 24 kW

FILAMENT CURRENT 10.6 A

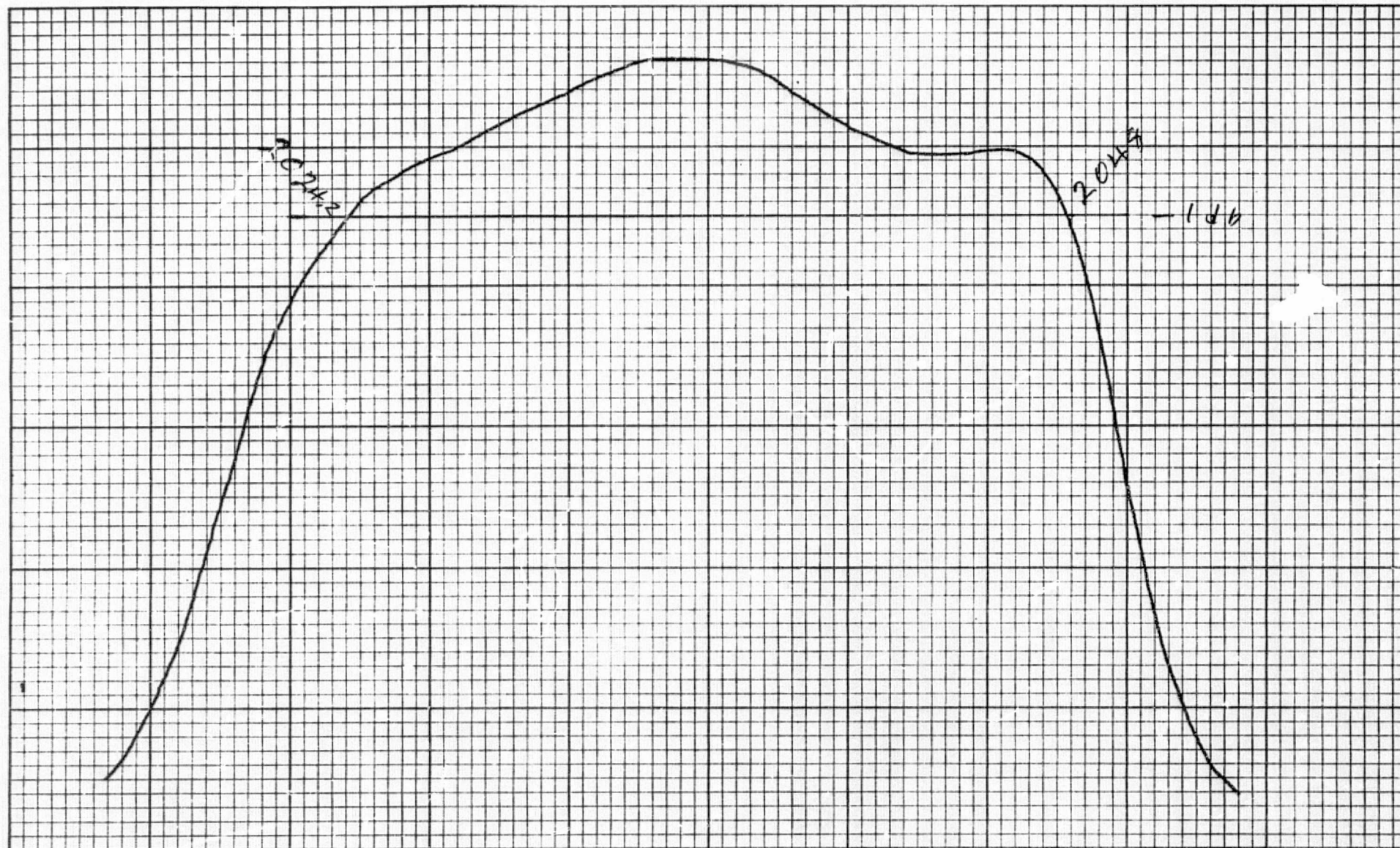
BEAM CURRENT 2.6 A

DRIVE POWER 540 mW

MAGNET CURRENT 16 A

BODY CURRENT 29 mA

GAIN 46.5 dB



FREQUENCY MHz

5K10SK UBT SERIAL NO. 2

CHANNEL 2

DATE: 6-2-75 BY: LLR/B

FILAMENT VOLTAGE 7.5 V

BEAM VOLTAGE 22 kV

POWER OUTPUT 1.2 kW

FILAMENT CURRENT 10.6 A

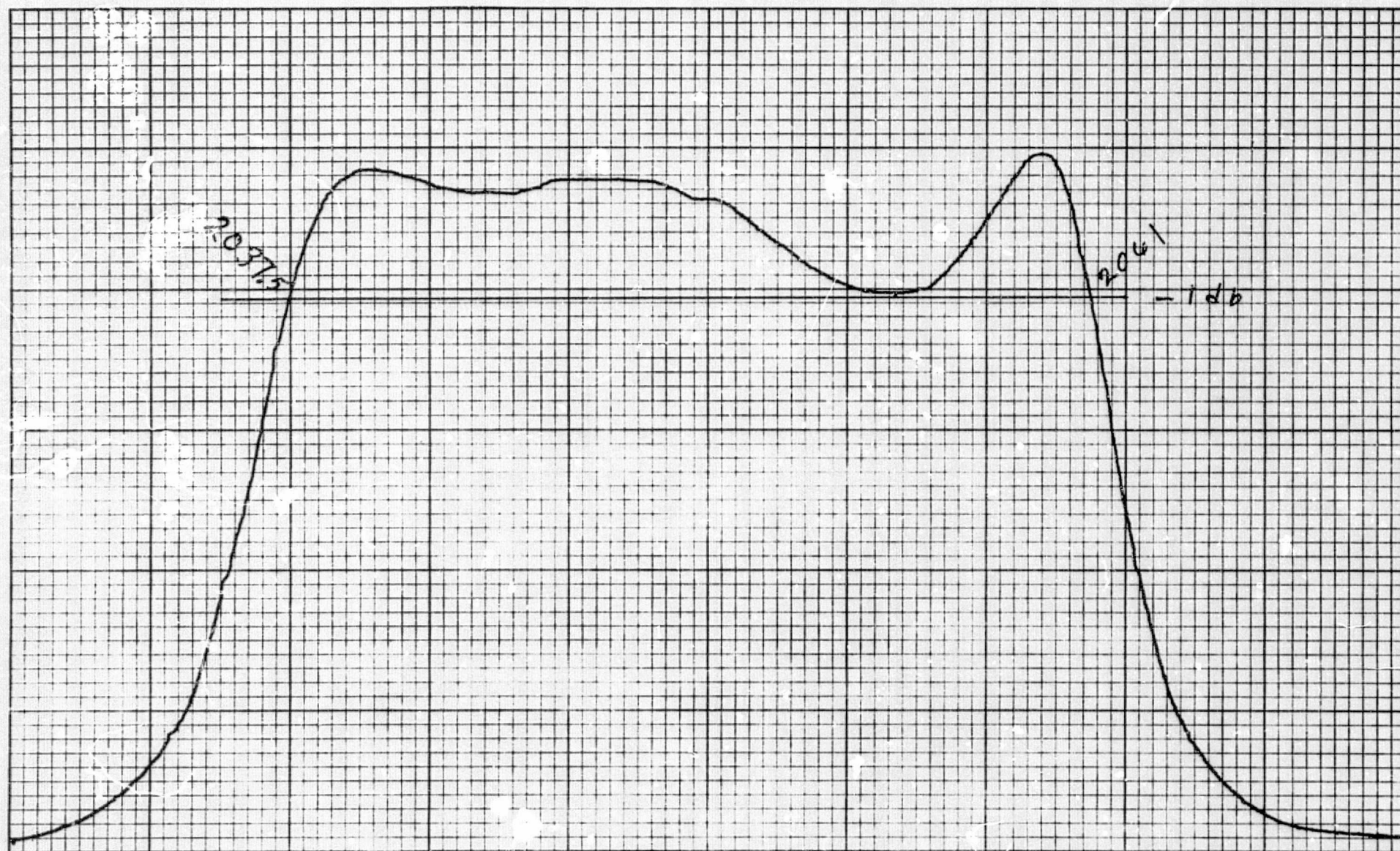
BEAM CURRENT 2.6 A

DRIVE POWER 8.7 mW

MAGNET CURRENT 16 A

BODY CURRENT 13 mA

GAIN 51.4 dB



5K70SK-WBT SERIAL NO. 2

CHANNEL 2

DATE: 6-2-75 BY: WAB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

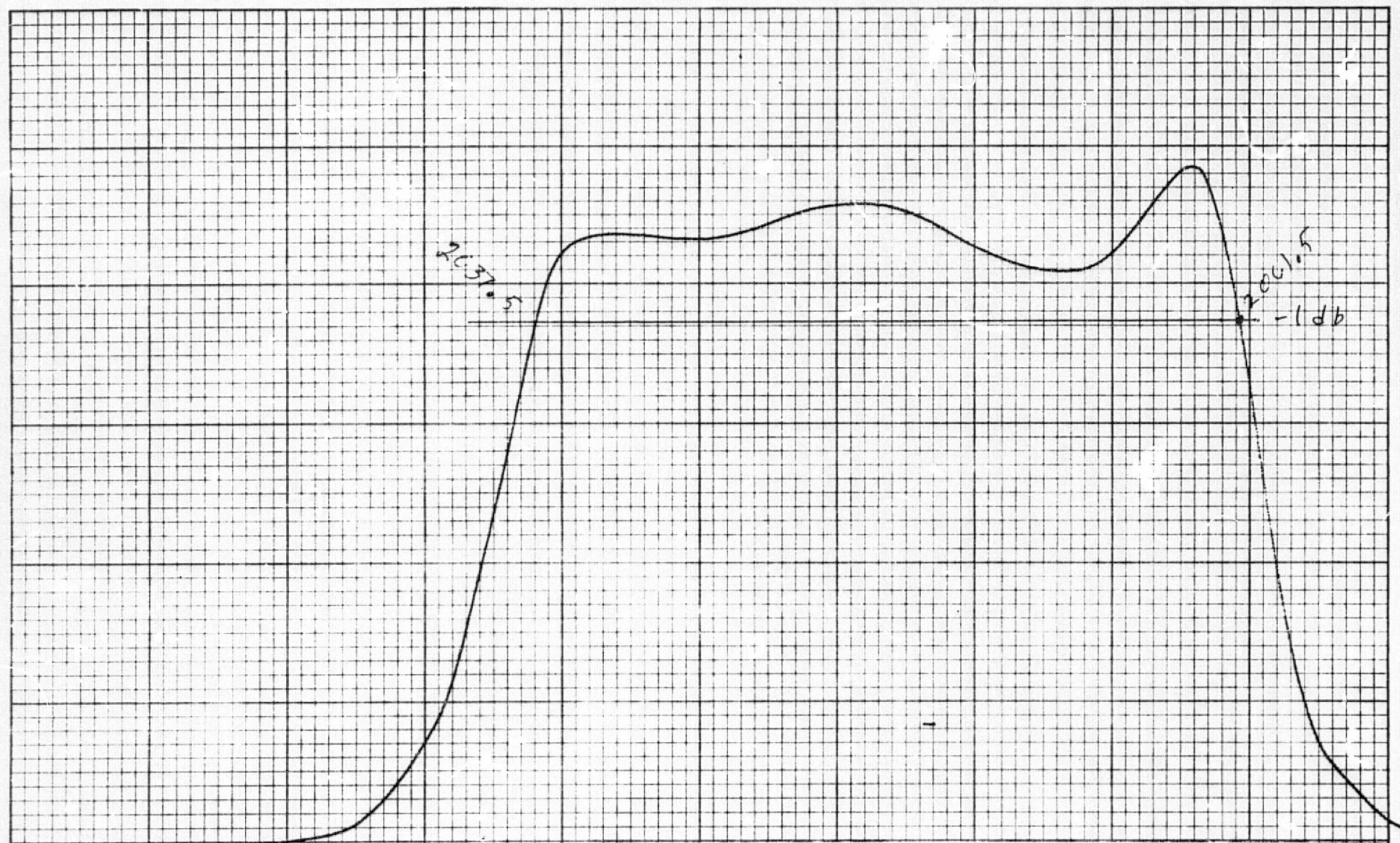
BEAM CURRENT 2.6 A

BODY CURRENT 13 mA

POWER OUTPUT 12 kW

DRIVE POWER 105 mW

GAIN 50.6 dB



FREQUENCY MHz - 26 -

5K1L5K-6BT SERIAL NO. 2

CHANNEL 2

DATE: 6-2-75 BY: U/RB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

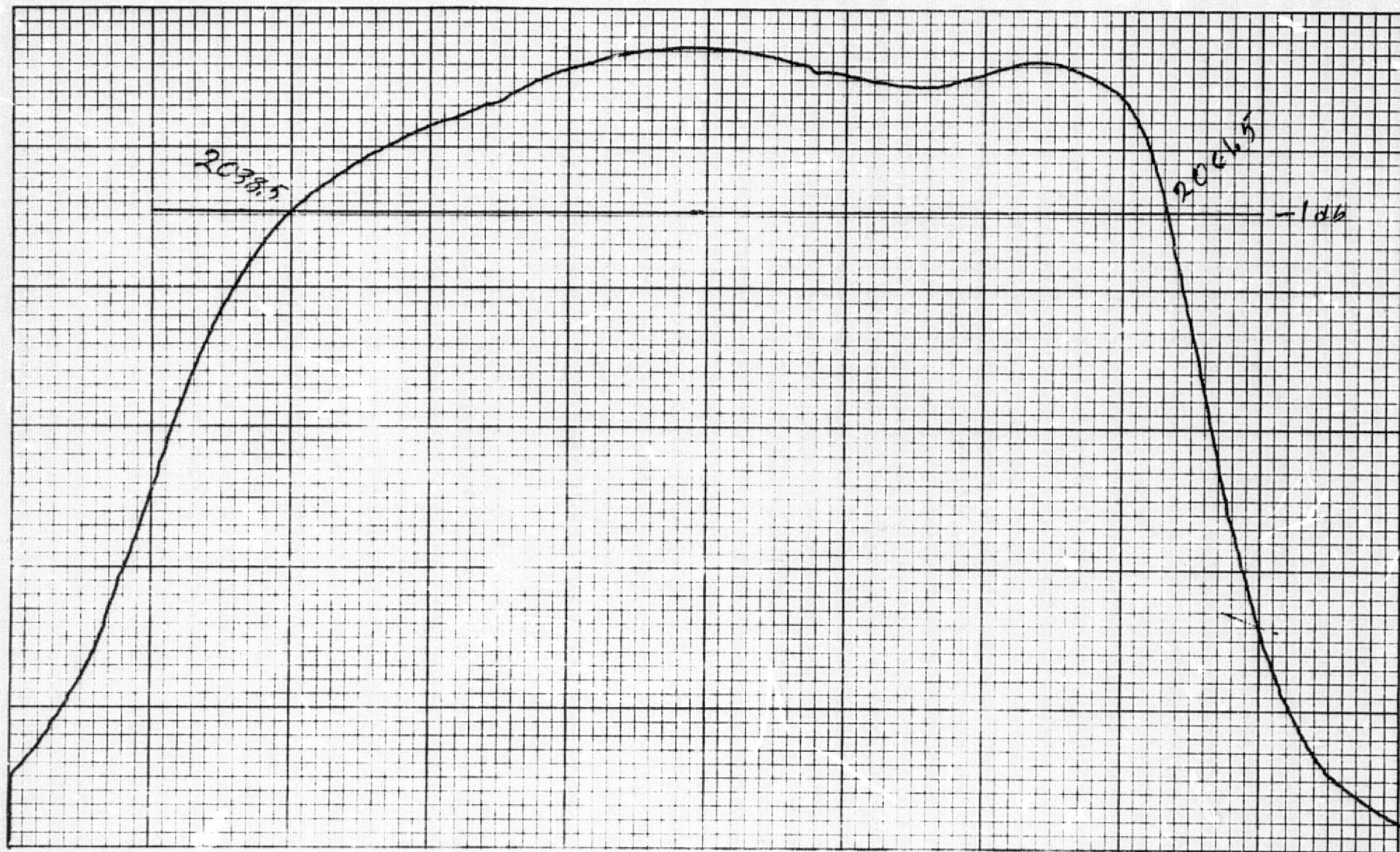
BEAM CURRENT 2.6 A

BODY CURRENT 25 mA

POWER OUTPUT 24 kW

DRIVE POWER 342 mW

GAIN 48.5 dB



ORIGINAL PAGE IS
OF POOR QUALITY

5K70SK-WBT SERIAL NO. 2

CHANNEL 3

DATE: 6-2-75 BY: W.R.B.

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

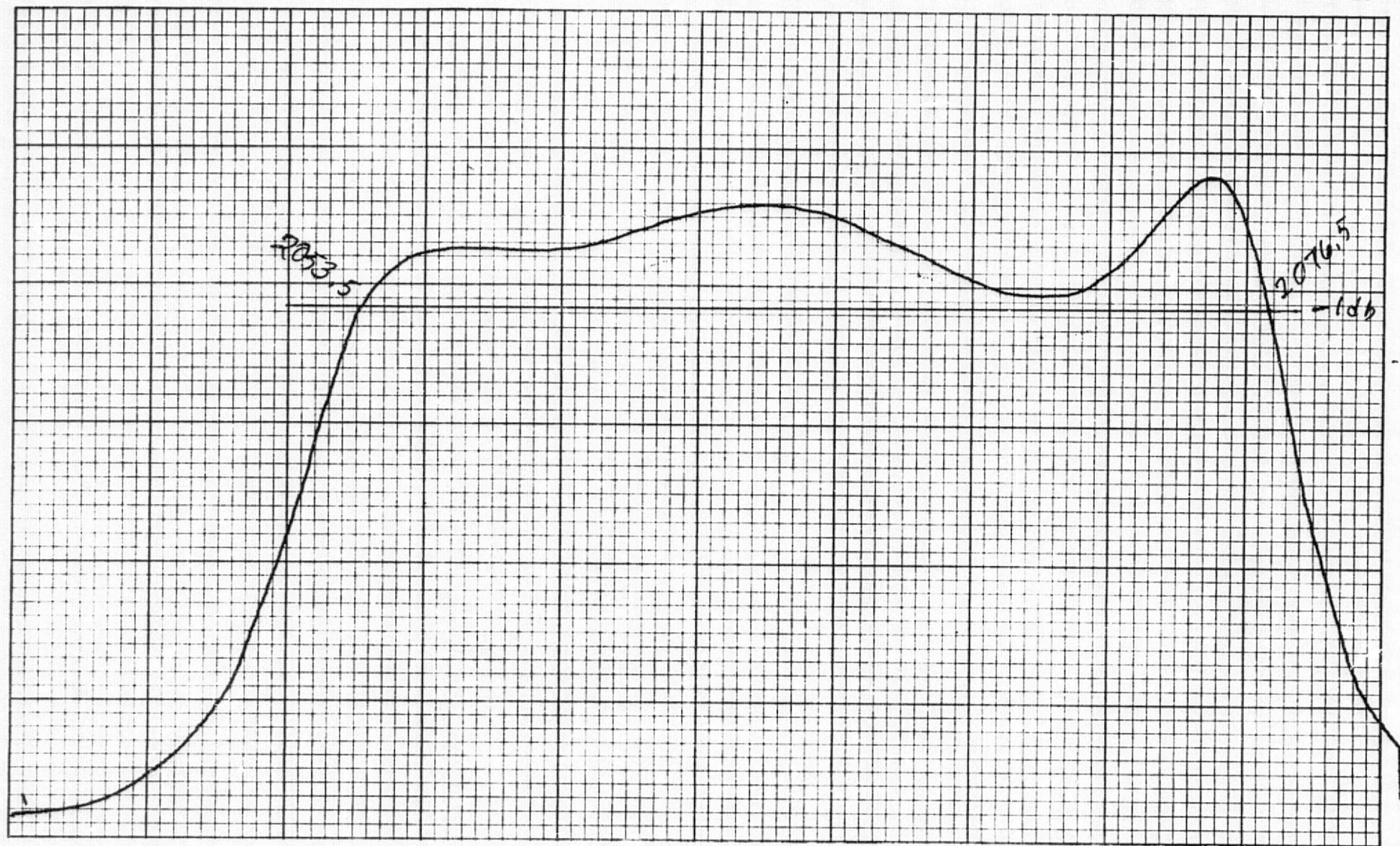
BEAM CURRENT 2.6 A

BODY CURRENT 12 mA

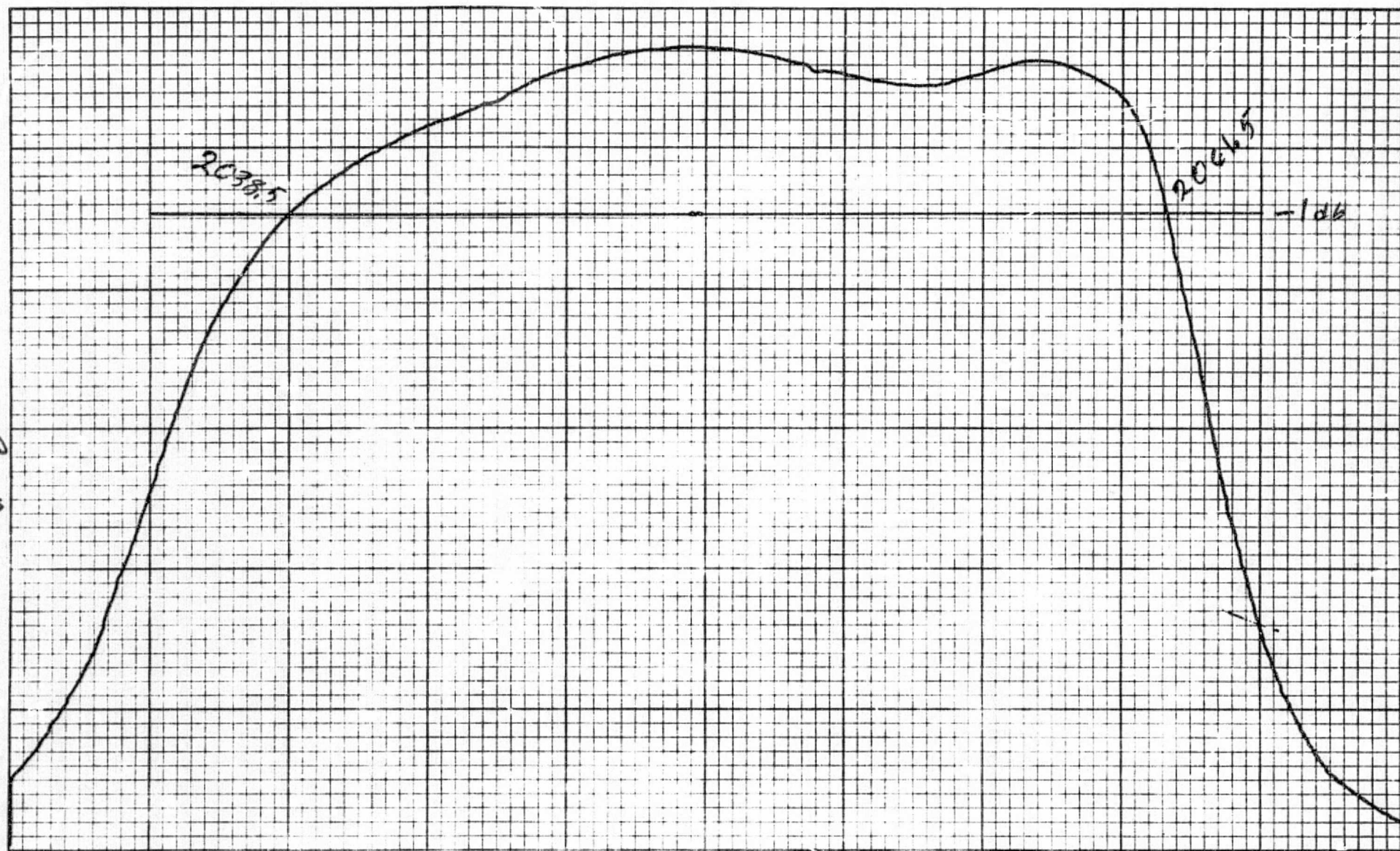
POWER OUTPUT 1.2 kW

DRIVE POWER 6.8 mW

GAIN 52.5 dB



FREQUENCY MHz

5K1L5K-UBT SERIAL NO. 2CHANNEL 2DATE: 6-2-75 BY: U/RBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 25 mAPOWER OUTPUT 24 kWDRIVE POWER 342 mWGAIN 48.5 dB

5K70SK-WBT SERIAL NO. 2

CHANNEL 3

DATE: 6-2-75 BY: W.R.B.

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

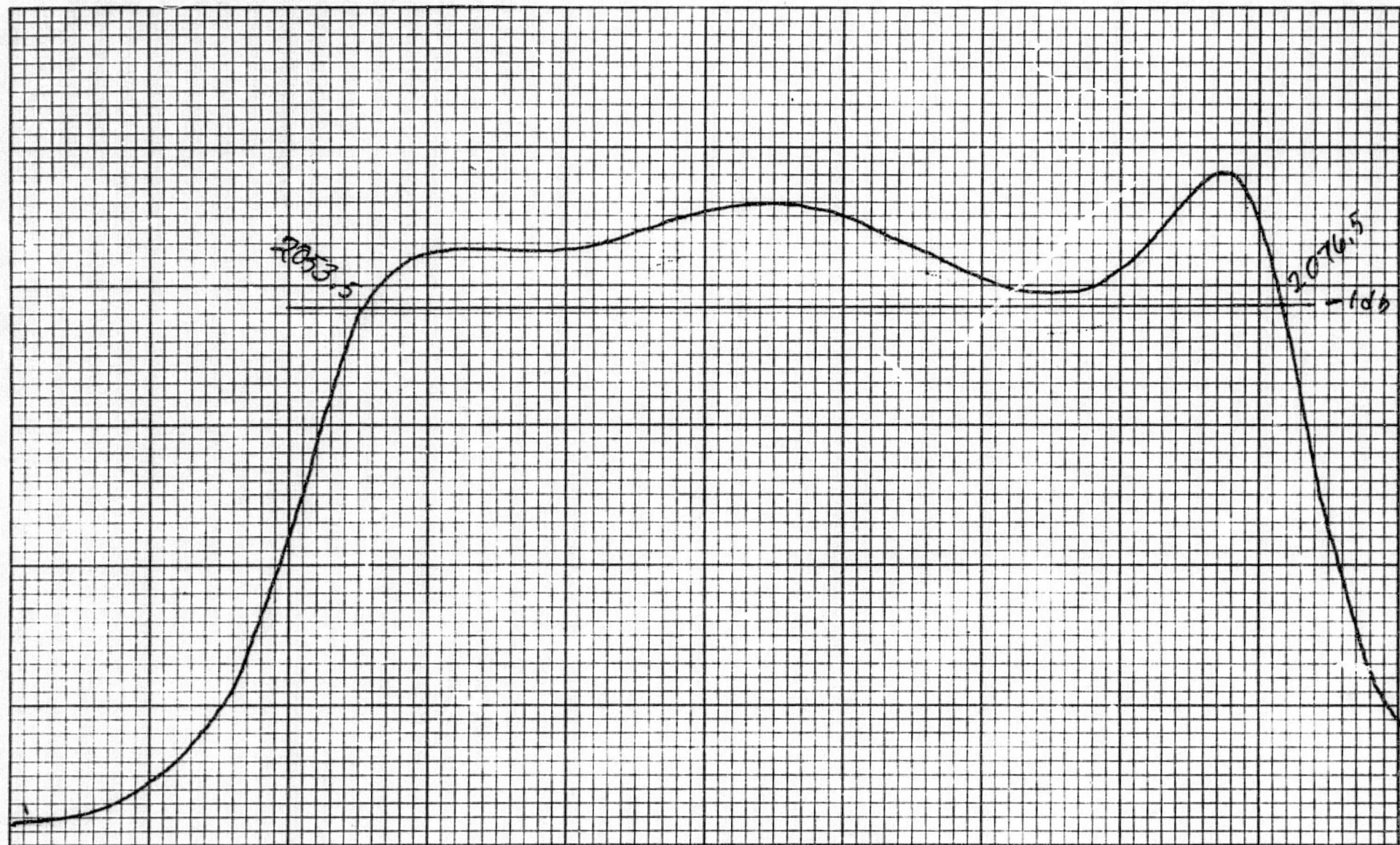
BEAM CURRENT 2.6 A

BODY CURRENT 12 mA

POWER OUTPUT 1.2 kW

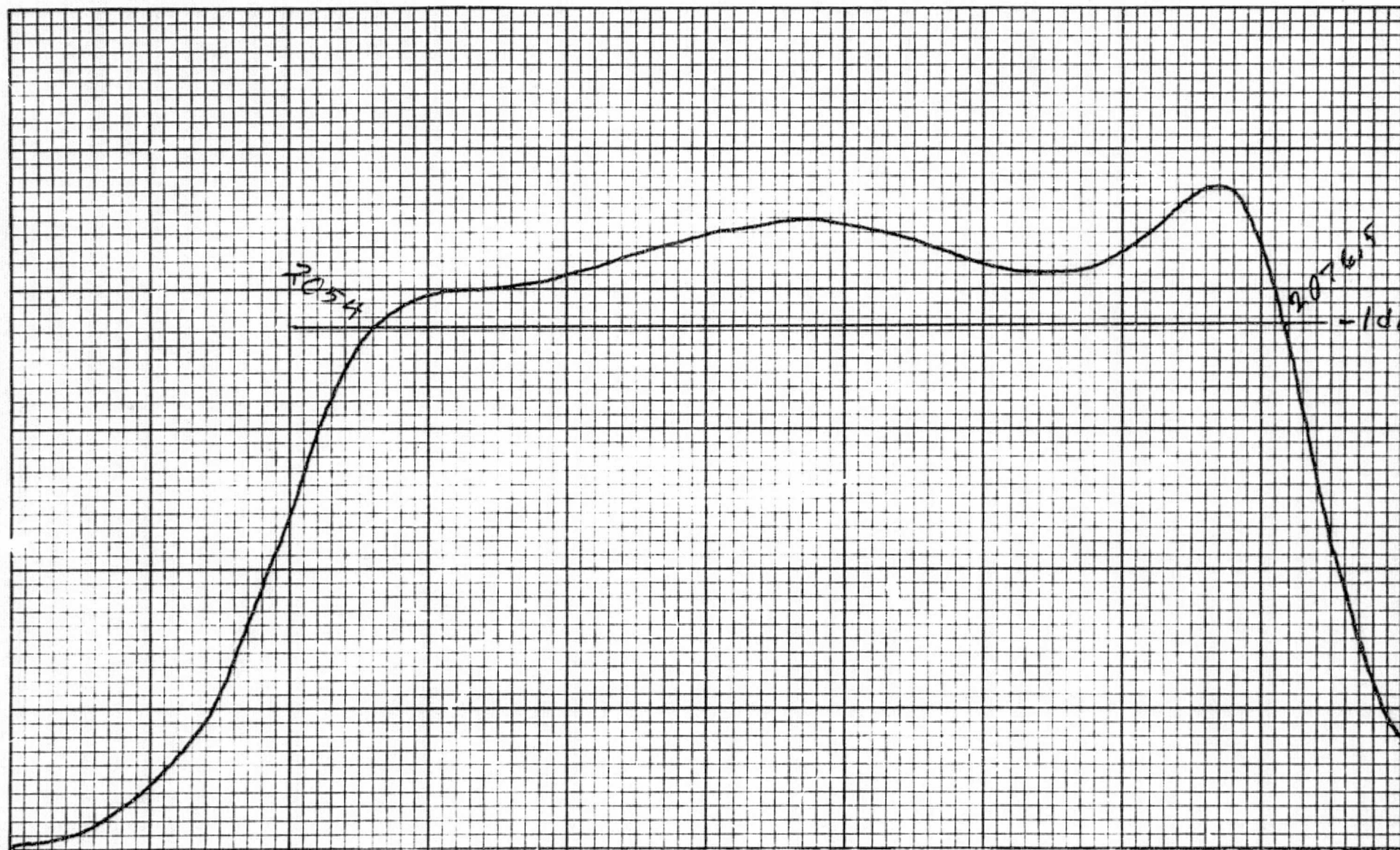
DRIVE POWER 6.8 mW

GAIN 52.5 dB



FREQUENCY MHz

- 26 -

5K7CSK-WBT SERIAL NO. 2CHANNEL 13DATE: 6-2-75 BY: W/RBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 16 mAPOWER OUTPUT 12 kWDRIVE POWER 100 mWGAIN 50.8 dB

FREQUENCY MHz - 26 -

POOR QUALITY

5K705K-WBT SERIAL NO. 2

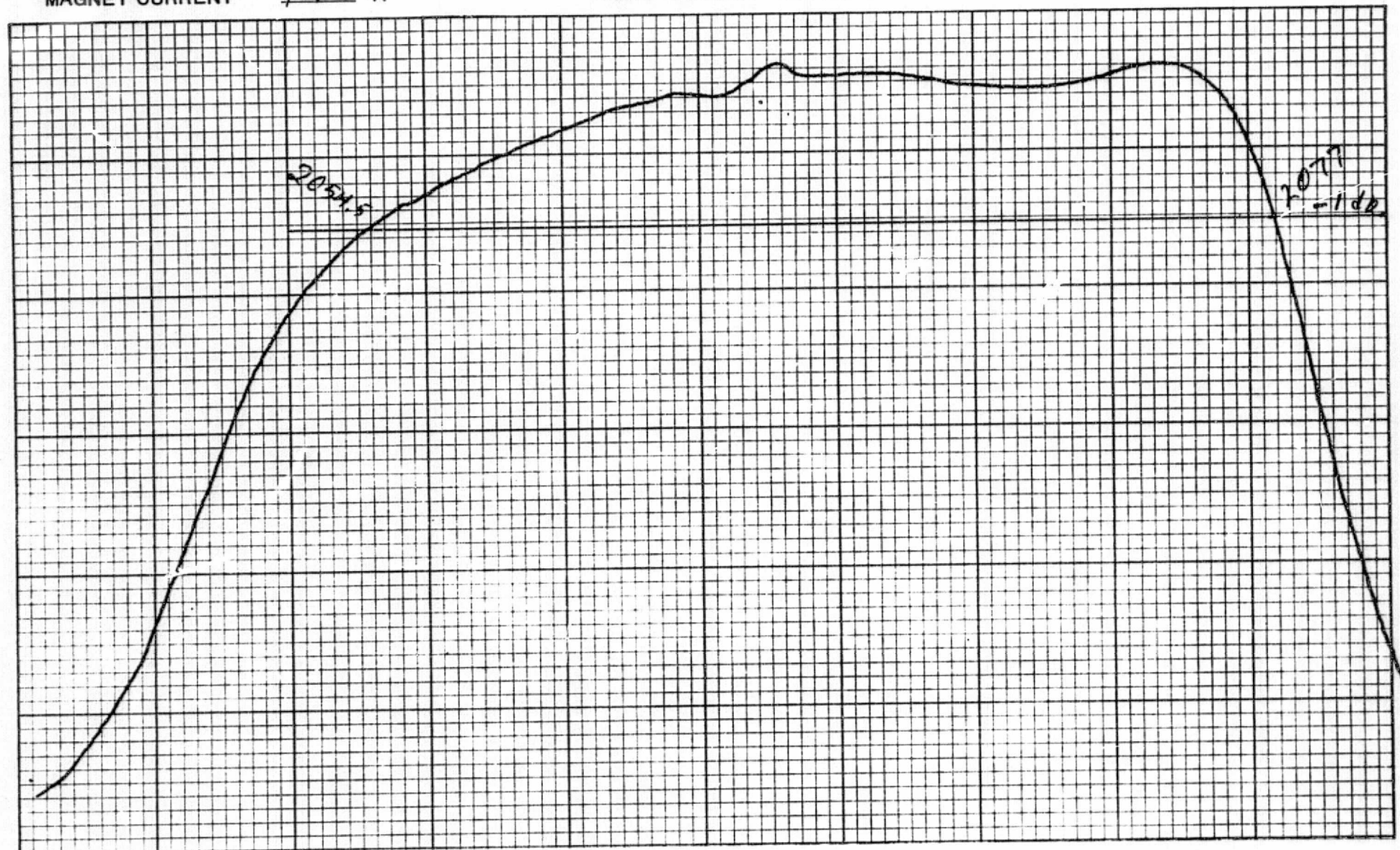
CHANNEL 9

DATE: 6-2-75 BY: WRB

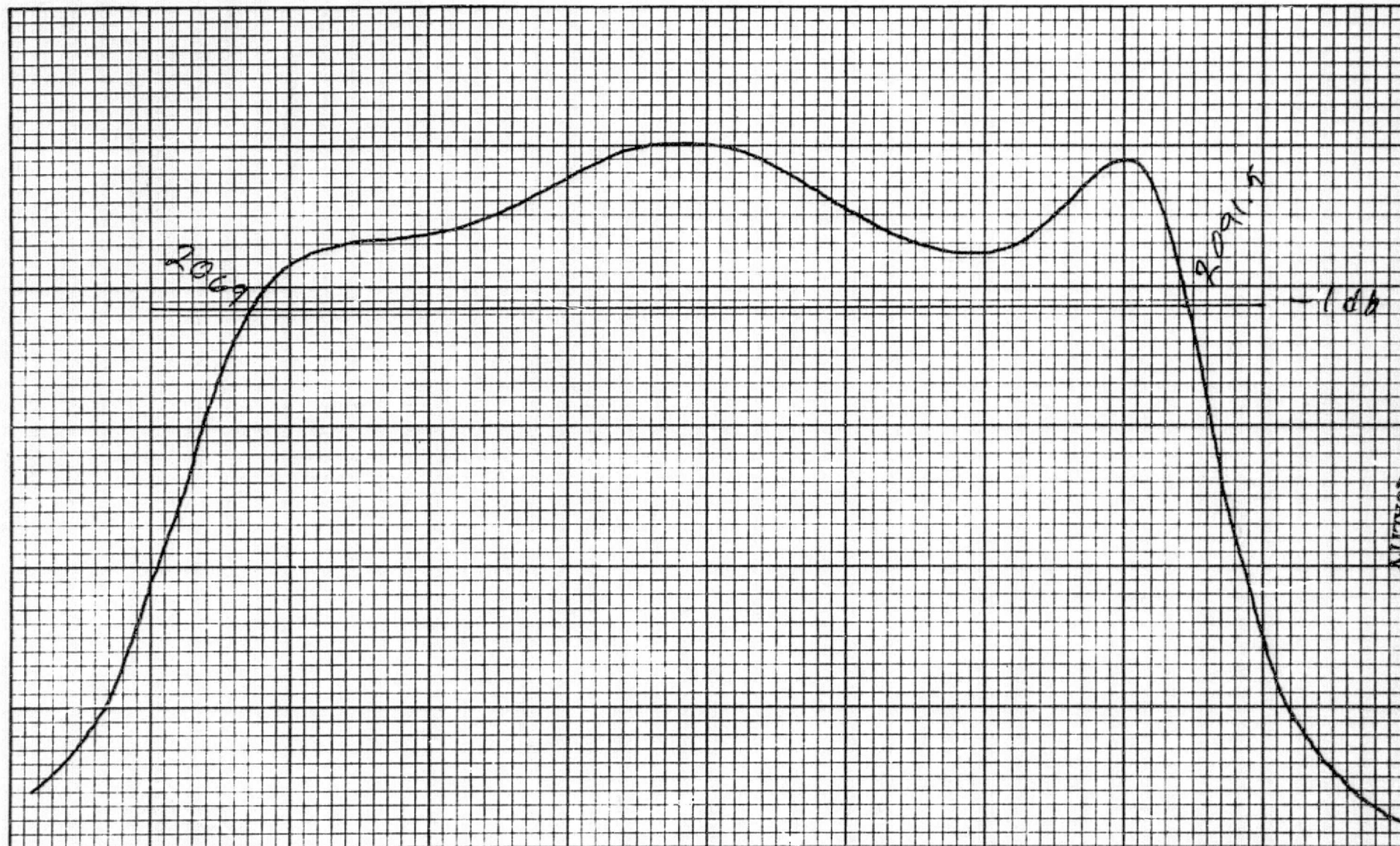
FILAMENT VOLTAGE 7.5 V
FILAMENT CURRENT 10.6 A
MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV
BEAM CURRENT 2.6 A
BODY CURRENT 30 mA

POWER OUTPUT 24 kW
DRIVE POWER 335 mW
GAIN 48.6 dB



FREQUENCY MHz

5K70SK-44BT SERIAL NO. 2CHANNEL 4DATE: 6-3-75 BY: WRBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 12 mAPOWER OUTPUT 1.2 kWDRIVE POWER 6.5 mWGAIN 52.7 dB

5K705K-UBT SERIAL NO. 2

CHANNEL A

DATE: 6-3-75 BY: W.R.B

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 1.6 A

BEAM VOLTAGE 22 kV

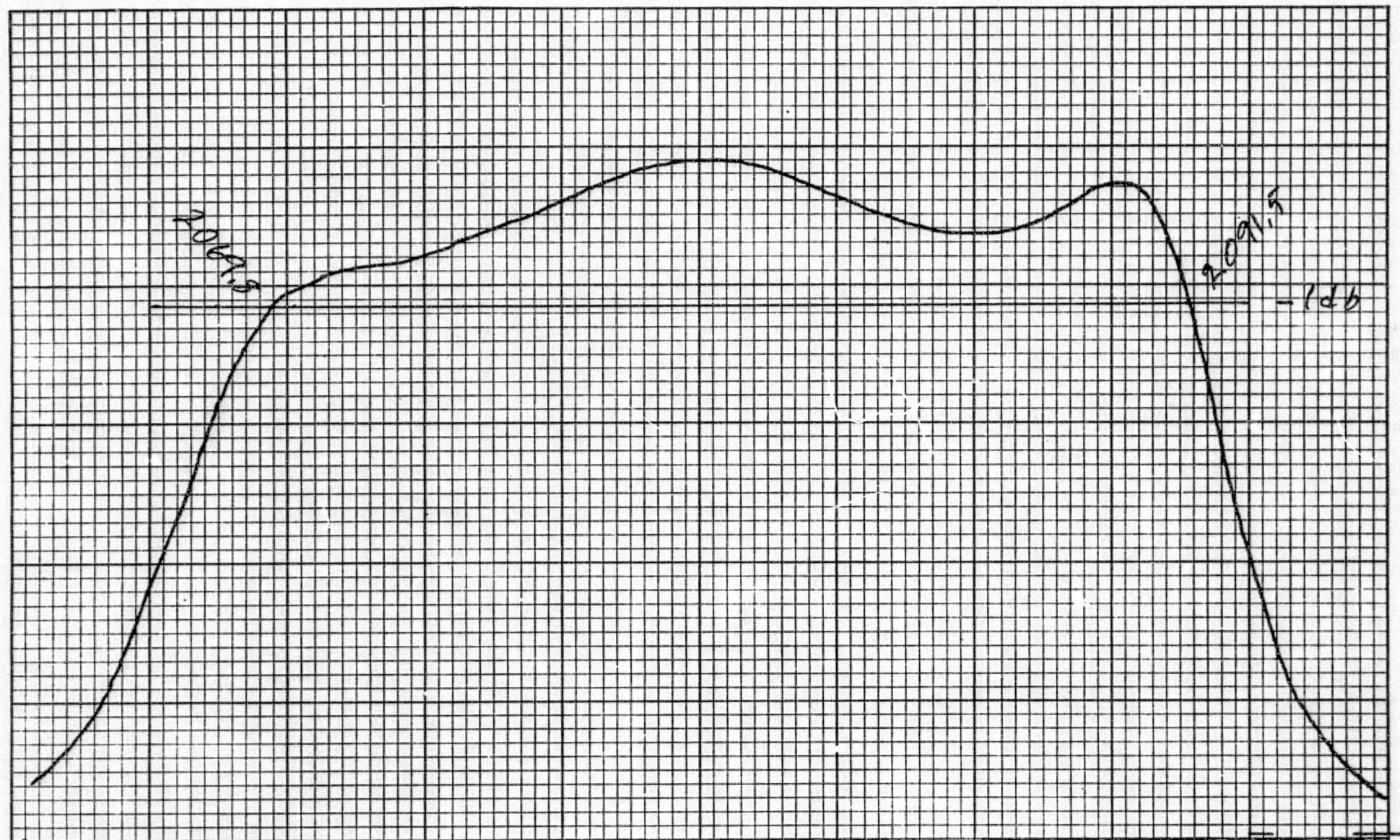
BEAM CURRENT 2.6 A

BODY CURRENT 20 mA

POWER OUTPUT 12 kW

DRIVE POWER 95 mW

GAIN 51.0 dB



FREQUENCY MHz - 26 -

5K10SK-4BT SERIAL NO. 1

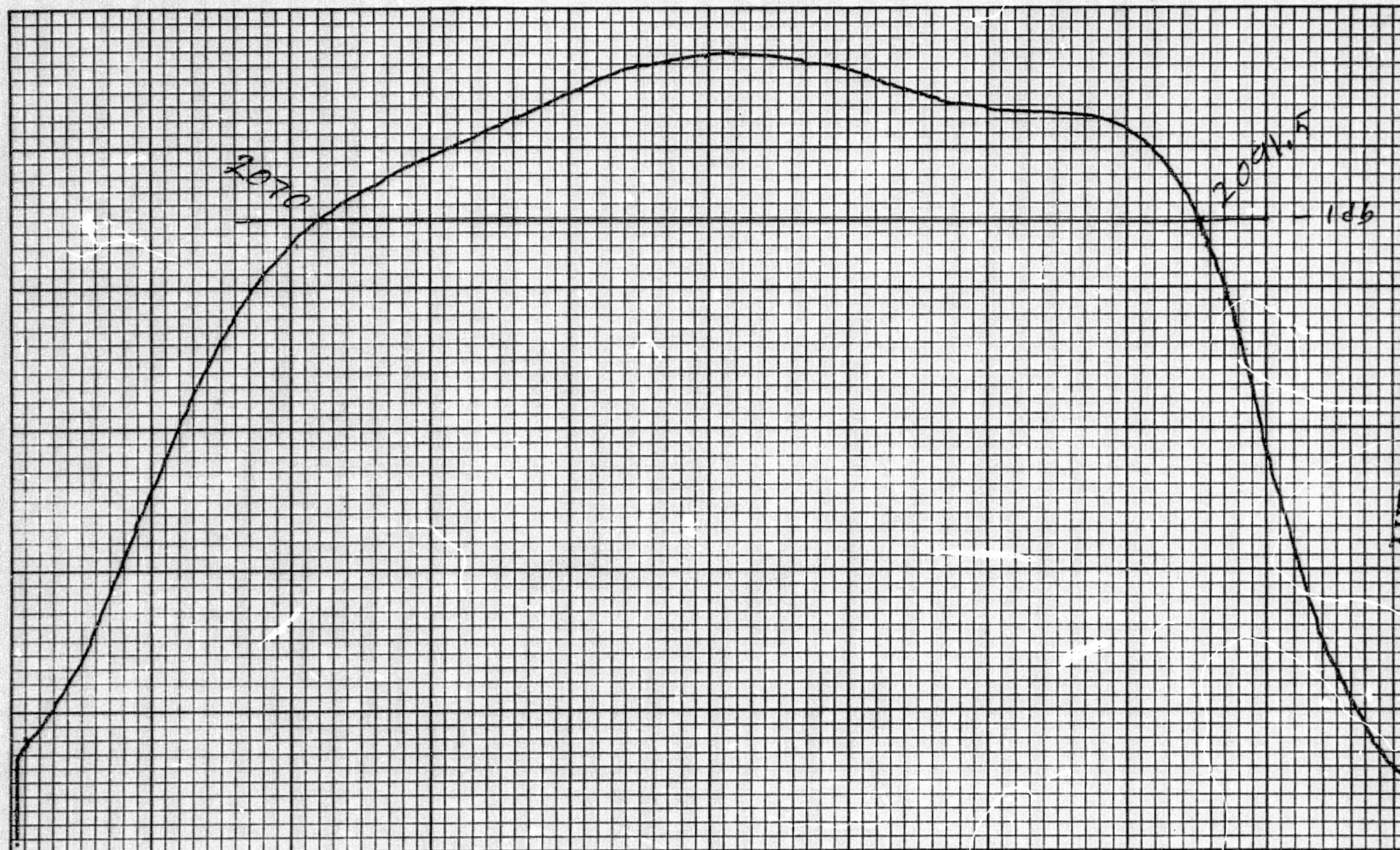
CHANNEL 4

DATE: 6-3-75 BY: W/RO

FILAMENT VOLTAGE 7.5 V
FILAMENT CURRENT 10.6 A
MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV
BEAM CURRENT 2.6 A
BODY CURRENT 40 mA

POWER OUTPUT 24 kW
DRIVE POWER 320 mW
GAIN 48.8 dB



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OF POOR QUALITY

5K70SK-11BT SERIAL NO. 2

CHANNEL 5

DATE: 6-3-75 BY: W/RB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

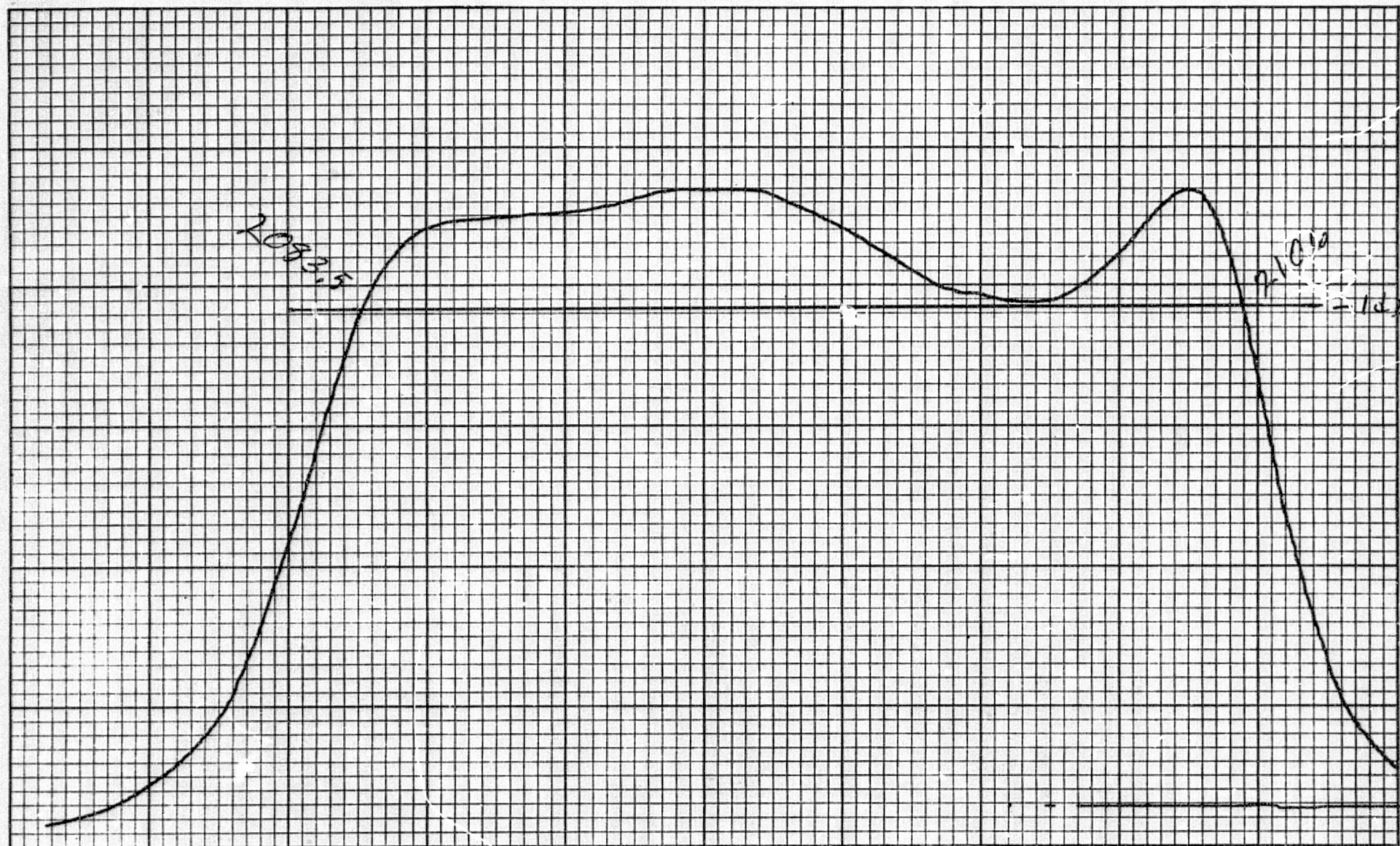
BEAM CURRENT 2.6 A

BODY CURRENT 12 mA

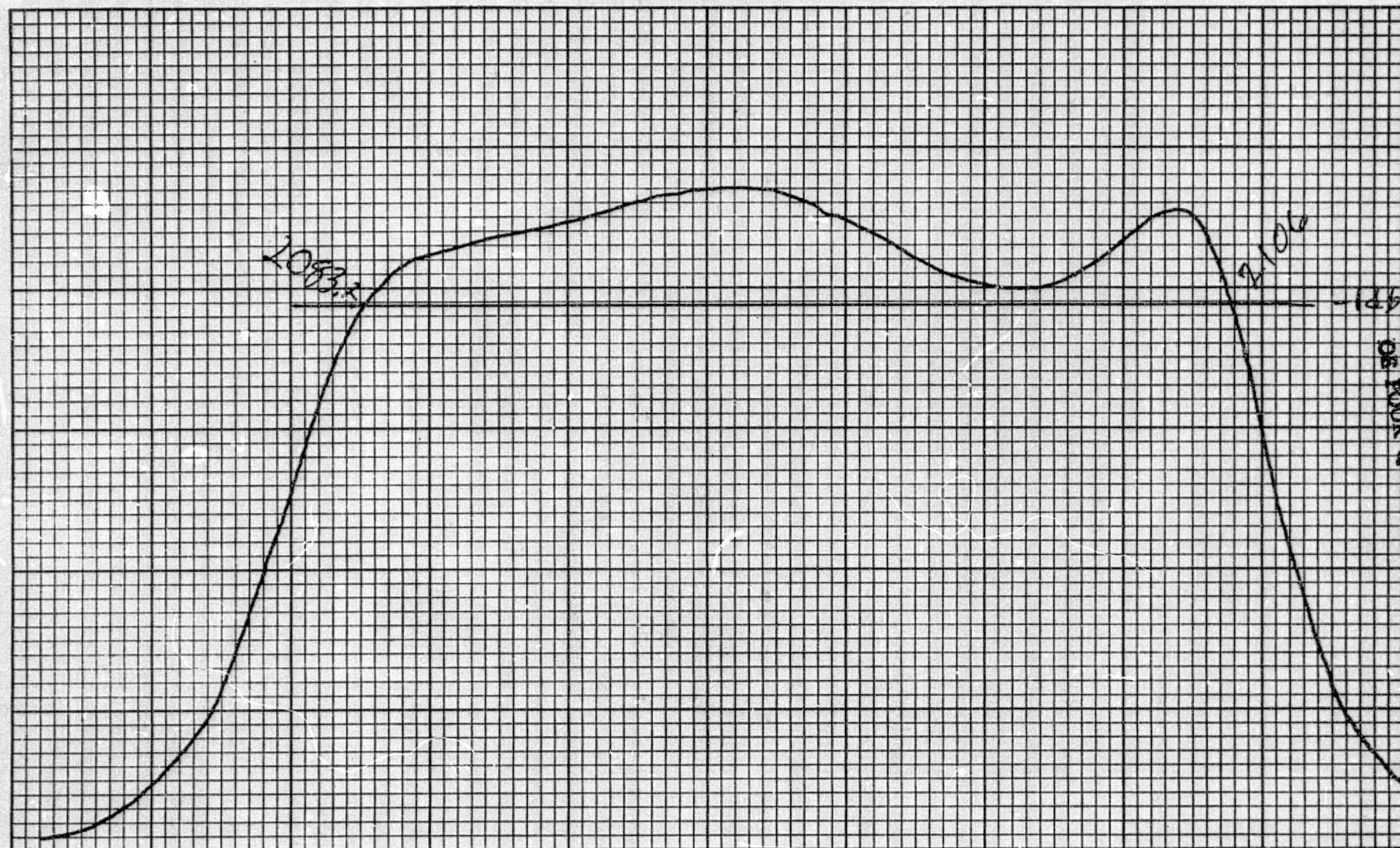
POWER OUTPUT 1.2 kW

DRIVE POWER 5.5 mW

GAIN 53.4 dB



FREQUENCY MHz - 26 -

5KT0SK-UBT SERIAL NO. 2CHANNEL 5DATE: 6-3-75 BY: WIBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 19 mAPOWER OUTPUT 12 kWDRIVE POWER 74 mWGAIN 52.1 dB

FREQUENCY MHz

- 26 -

5K705K-WBT SERIAL NO. 2

CHANNEL 5

DATE: 6-3-75 BY: WFB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

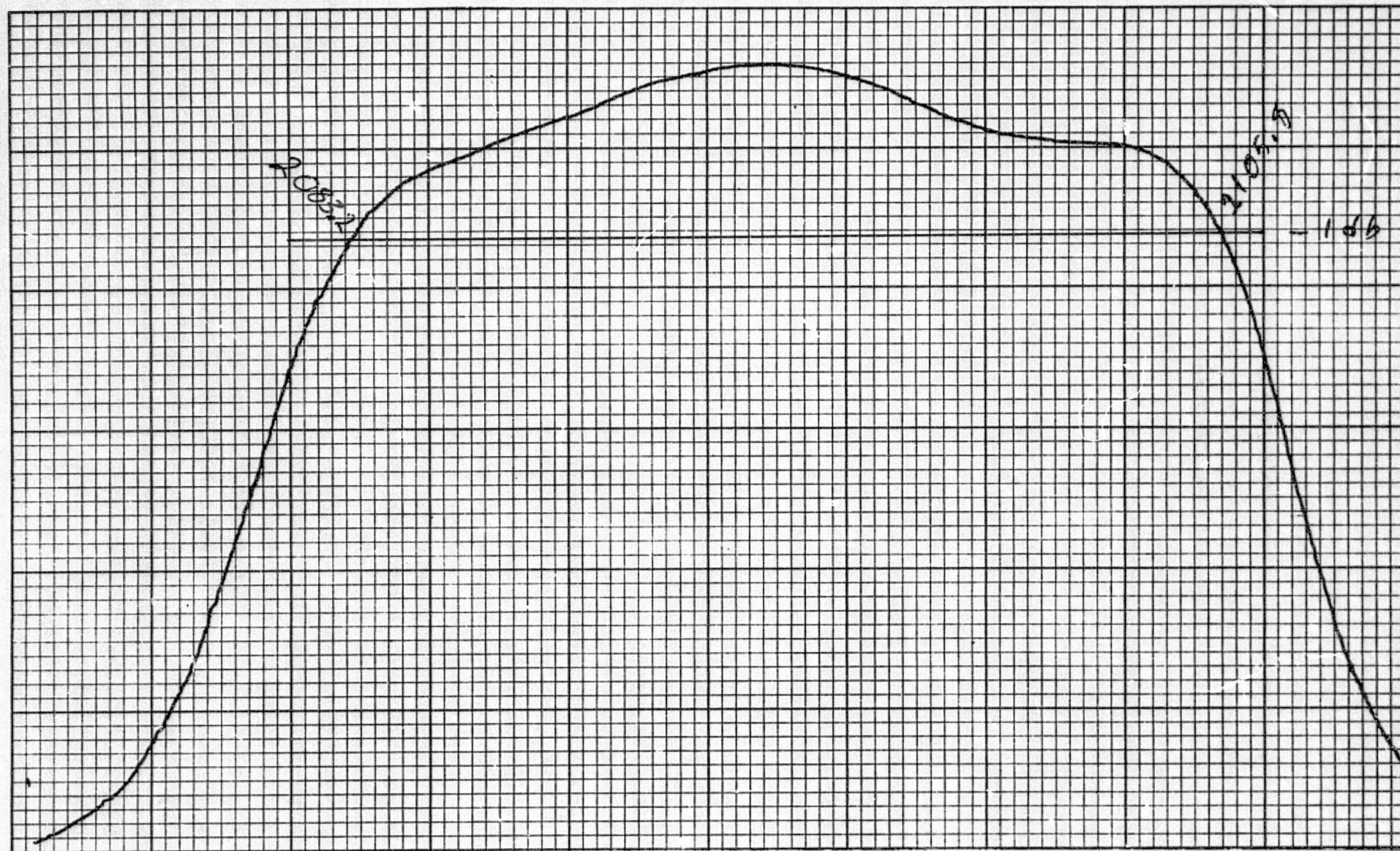
BEAM CURRENT 2.6 A

BODY CURRENT 35 mA

POWER OUTPUT 24 kW

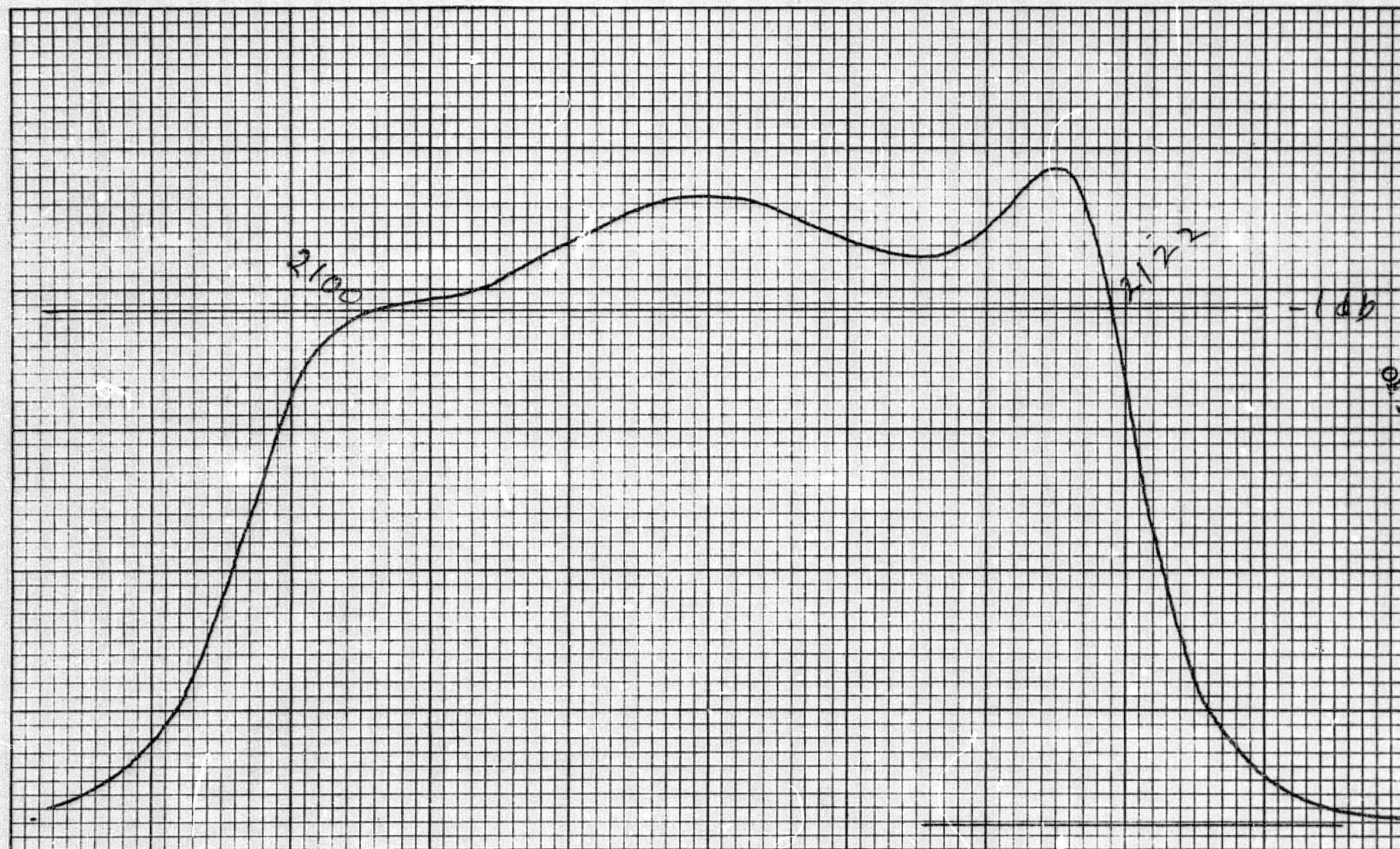
DRIVE POWER 220 mW

GAIN 50.4 dB



FREQUENCY MHz

- 26 -

5K7L5K-6BT SERIAL NO. 2CHANNEL 6DATE: 6-3-75 BY: W.B.17FILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 14 mAPOWER OUTPUT 1.2 kWDRIVE POWER 8.7 mWGAIN 51.4 dBORIGINAL
OF FOUR QU

5K705K-WBT SERIAL NO. 2

CHANNEL 6

DATE: 6-3-75 BY: WRB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

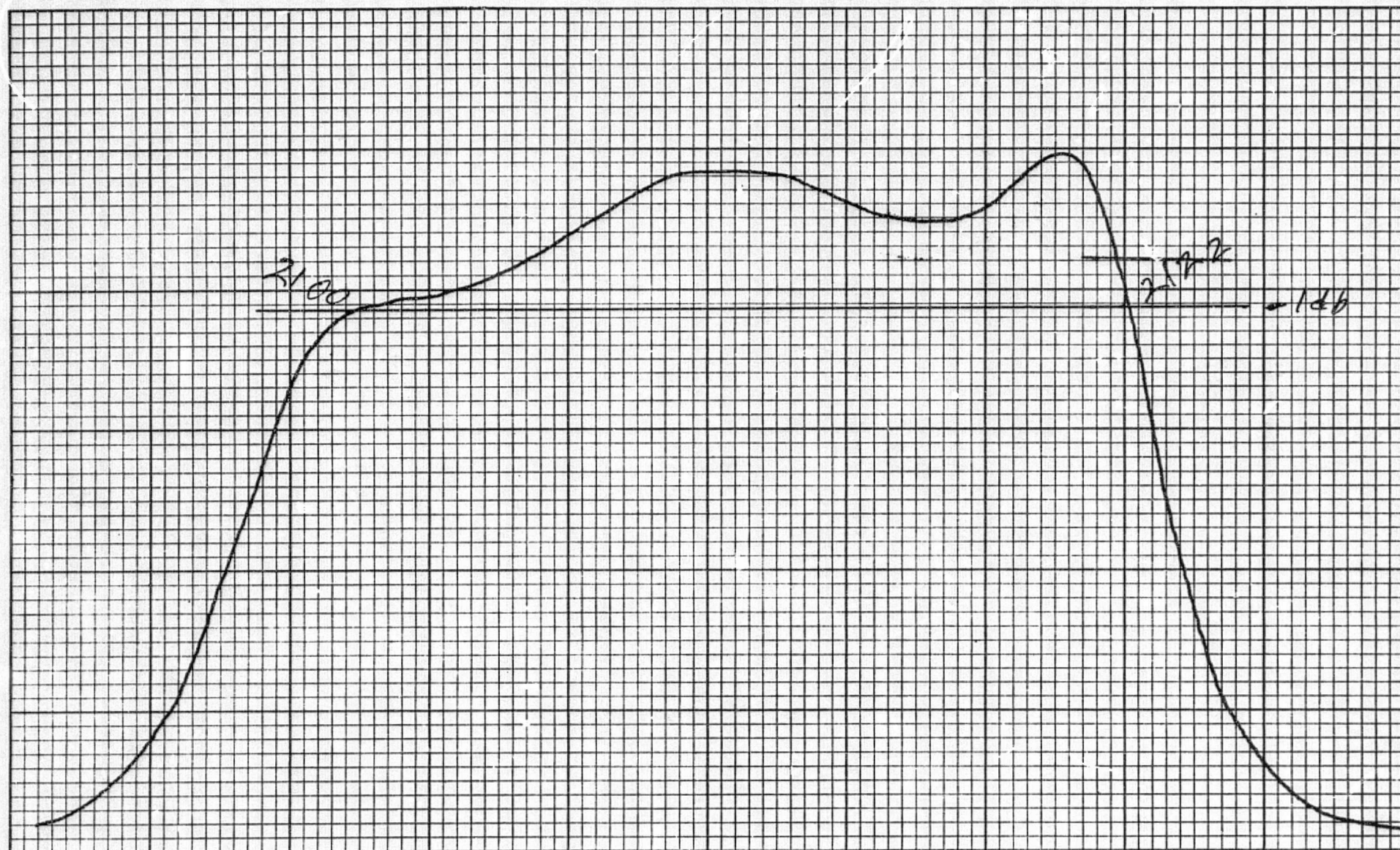
BEAM CURRENT 2.6 A

BODY CURRENT 15 mA

POWER OUTPUT 12 kW

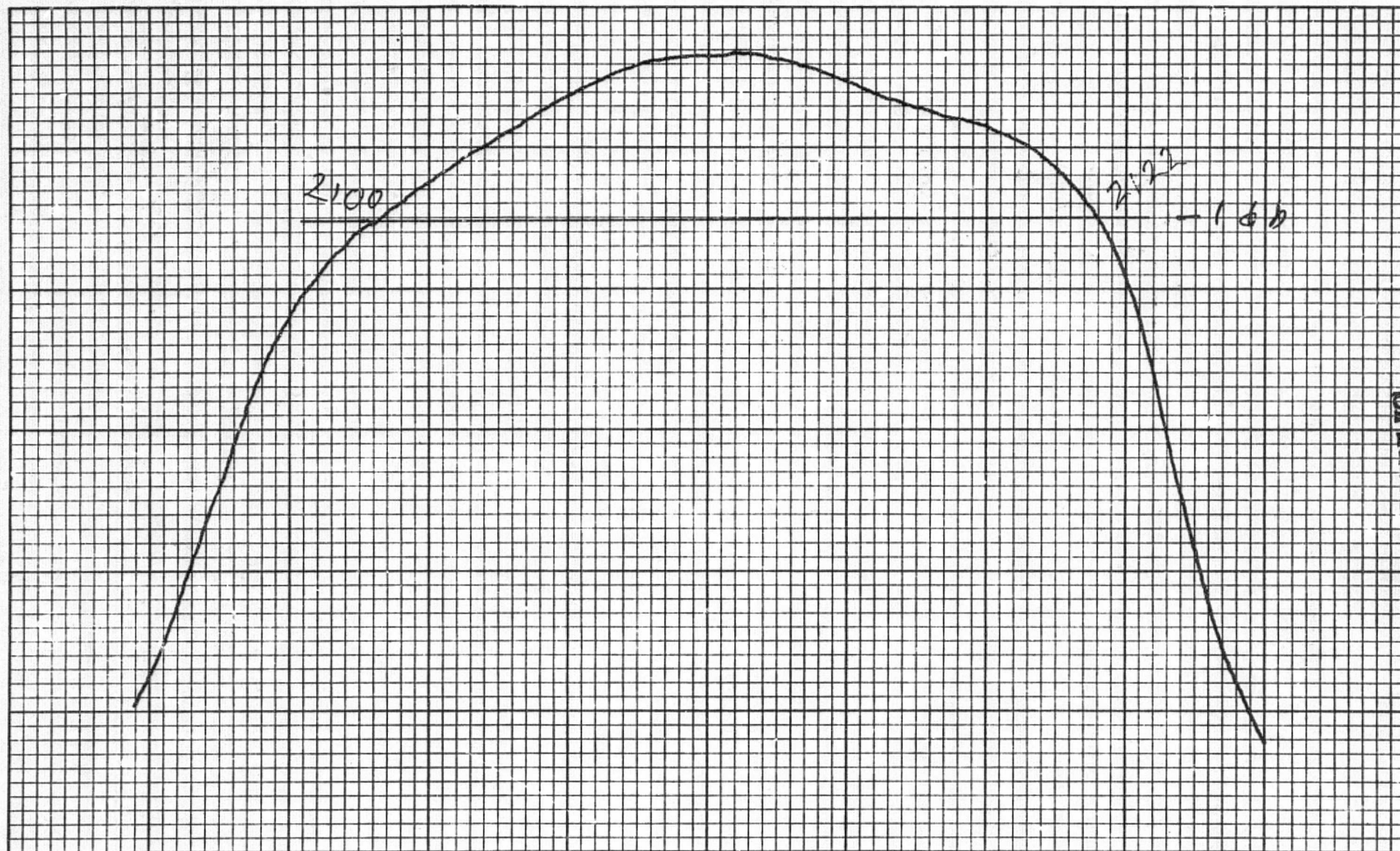
DRIVE POWER 126 mW

GAIN 49.8 dB



FREQUENCY MHz

- 26 -

5K7CSK-UBT SERIAL NO. 2CHANNEL 6DATE: 6-3-75 BY: U R DFILAMENT VOLTAGE 2.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 32 mAPOWER OUTPUT 24 kWDRIVE POWER 420 mWGAIN 47.6 dBORIGINAL PAGE IS
OF GOOD QUALITY

OUTPUT POWER STABILITY TEST

<u>Parameter</u>	<u>Symbol</u>	
Beam Voltage	Eb	<u>22 kVdc</u>
Beam Current	Ib	<u>2.6 Adc</u>
Filament Voltage	Ef	<u>7.5 Vac</u>
R.F. Drive Power	Pd	<u>335 mW</u>
Magnet Current	Im	<u>16 Adc</u>
Frequency	F	<u>2110 MHz</u>
Inlet Water Temp.	To	<u>21.5 °C</u>
Power Output	Po	<u>24 kW</u>

Time	Thr	<u>0</u>	<u>2</u>	<u>4</u>	<u>6</u>	<u>8</u>
Power Output	Po	<u>24</u>	<u>24.2</u>	<u>24.1</u>	<u>24.23</u>	<u>24.3</u>

COMMENTS:

Tested by Art Goldfinger

Varian QAR Ron Jones 

Customer QAR Howard Kington

Date 6/5/75

Date 6/5/75

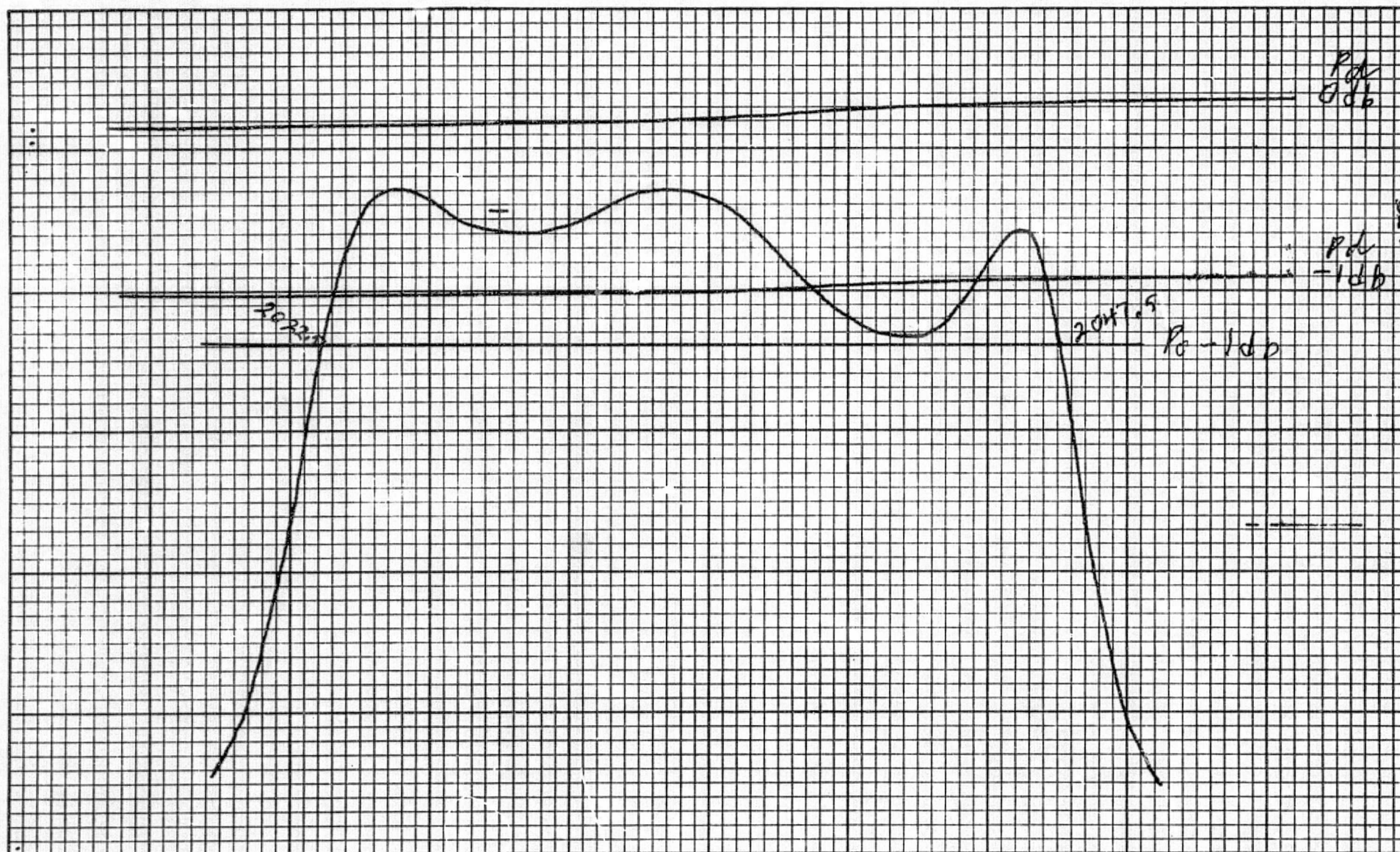
Date 6/6/75

6.0 Test Performance Data Sheet

6.9.1 Output Power Stability

SERIAL NO. 2CHANNEL 1DATE: C-4-75 BY: WKBFILAMENT VOLTAGE 7.5 VBEAM VOLTAGE 22 kVPOWER OUTPUT 1.2 kWFILAMENT CURRENT 10.6 ABEAM CURRENT 2.6 ADRIVE POWER 13 mWMAGNET CURRENT 16 ABODY CURRENT 12 mA

GAIN _____ dB

ORIGINAL PAGE IS
OF POOR QUALITY

SERIAL NO. 2

CHANNEL 1

DATE: 6-4-75 BY: WRB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

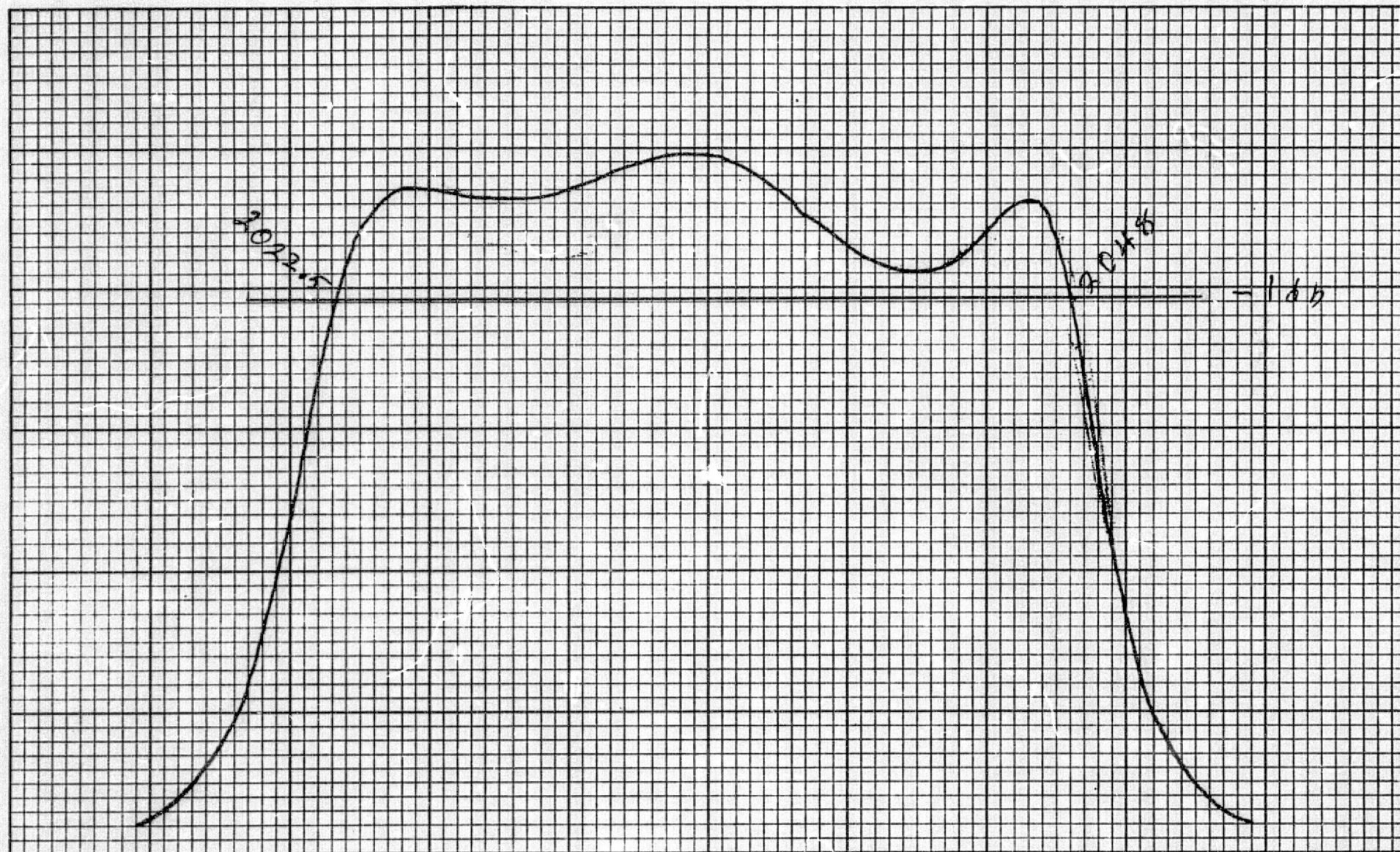
BEAM CURRENT 2.6 A

BODY CURRENT 15 mA

POWER OUTPUT 12 kW

DRIVE POWER 162 mW

GAIN _____ dB



FREQUENCY MHz - 28 -

SERIAL NO. 2

CHANNEL 1

DATE: 6-4-75 BY: WKB

FILAMENT VOLTAGE 7.5 V

BEAM VOLTAGE 22 kV

POWER OUTPUT 2.4 kW

FILAMENT CURRENT 10.6 A

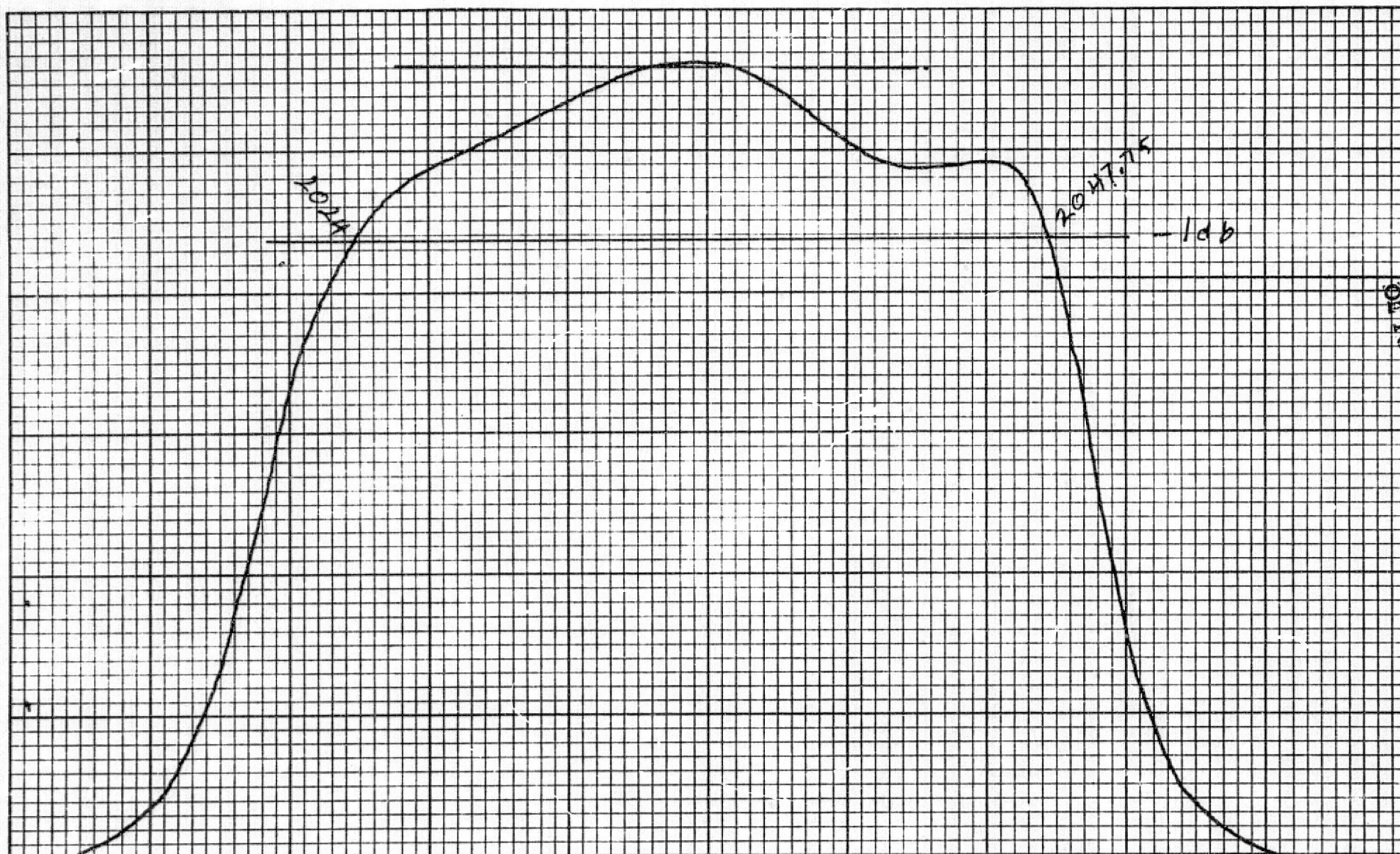
BEAM CURRENT 2.6 A

DRIVE POWER 510 mW

MAGNET CURRENT 16 A

BODY CURRENT 25 mA

GAIN _____ dB



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OF POOR QUALITY

SERIAL NO. 2

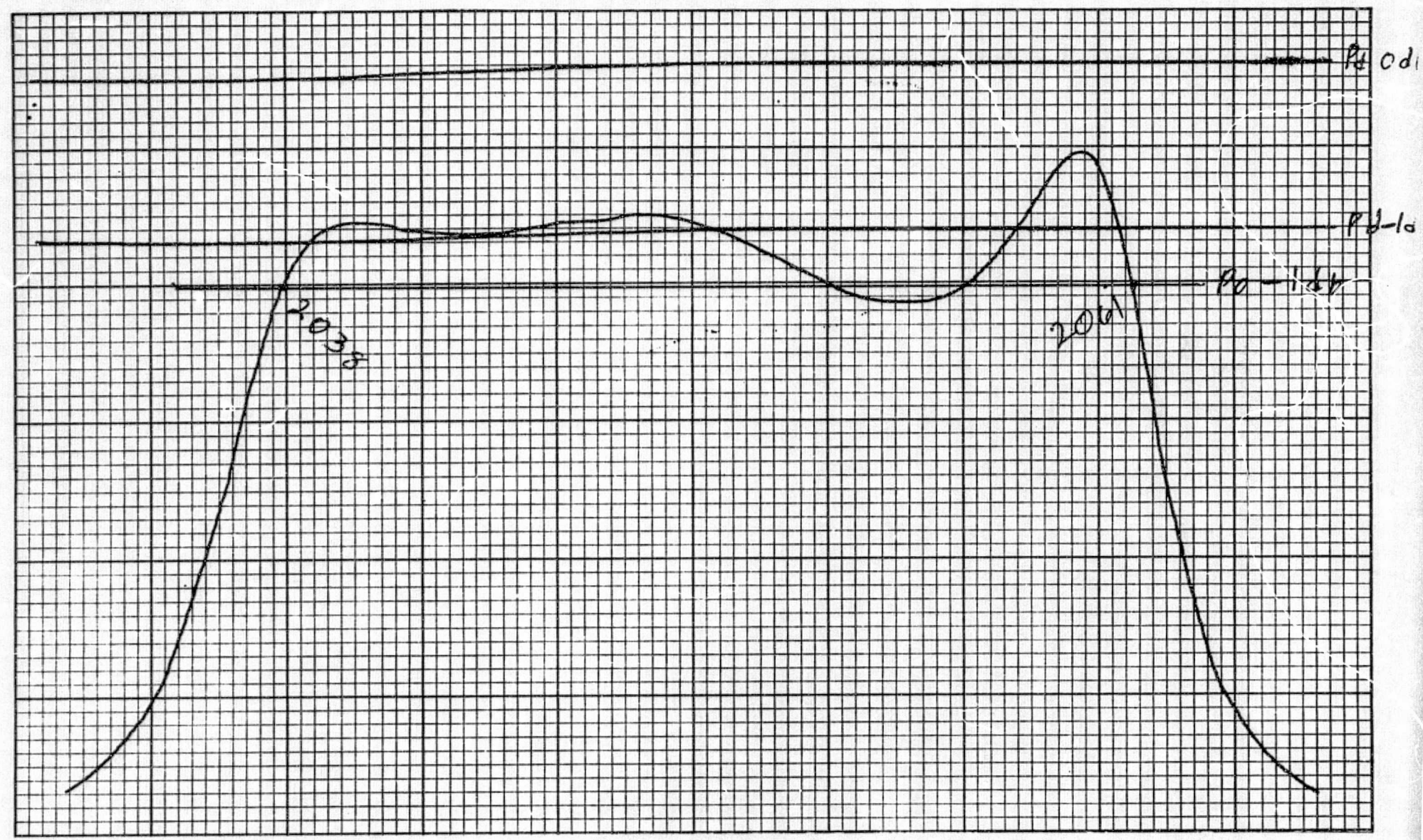
CHANNEL 2

DATE: 6-4-75 BY: WRB

FILAMENT VOLTAGE 7.5 V
FILAMENT CURRENT 10.6 A
MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV
BEAM CURRENT 2.6 A
BODY CURRENT 12 mA

POWER OUTPUT 1.2 kW
DRIVE POWER 7.3 mW
GAIN _____ dB



SERIAL NO. 2

CHANNEL 2
22KV → 12.0KV

DATE: 6/4/75 BY: _____

FILAMENT VOLTAGE _____ V

BEAM VOLTAGE _____ kV

POWER OUTPUT 1.28 kW

FILAMENT CURRENT _____ A

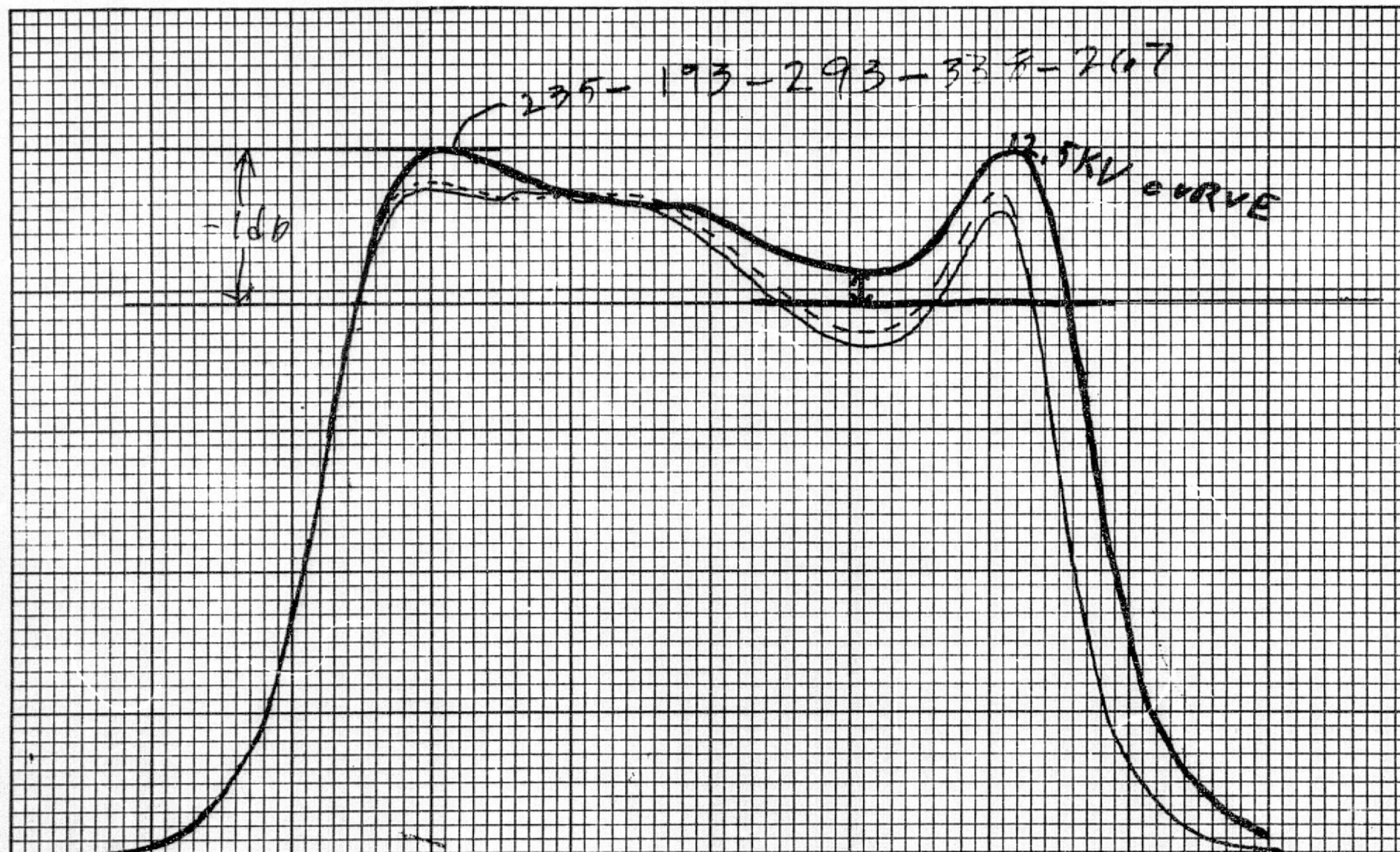
BEAM CURRENT 1.1 A

DRIVE POWER 300 mW

MAGNET CURRENT _____ A

BODY CURRENT 12 mA

GAIN 30 dB



ORIGINAL PAGE 12
OF 2008 QUANTITY

SERIAL NO. 2

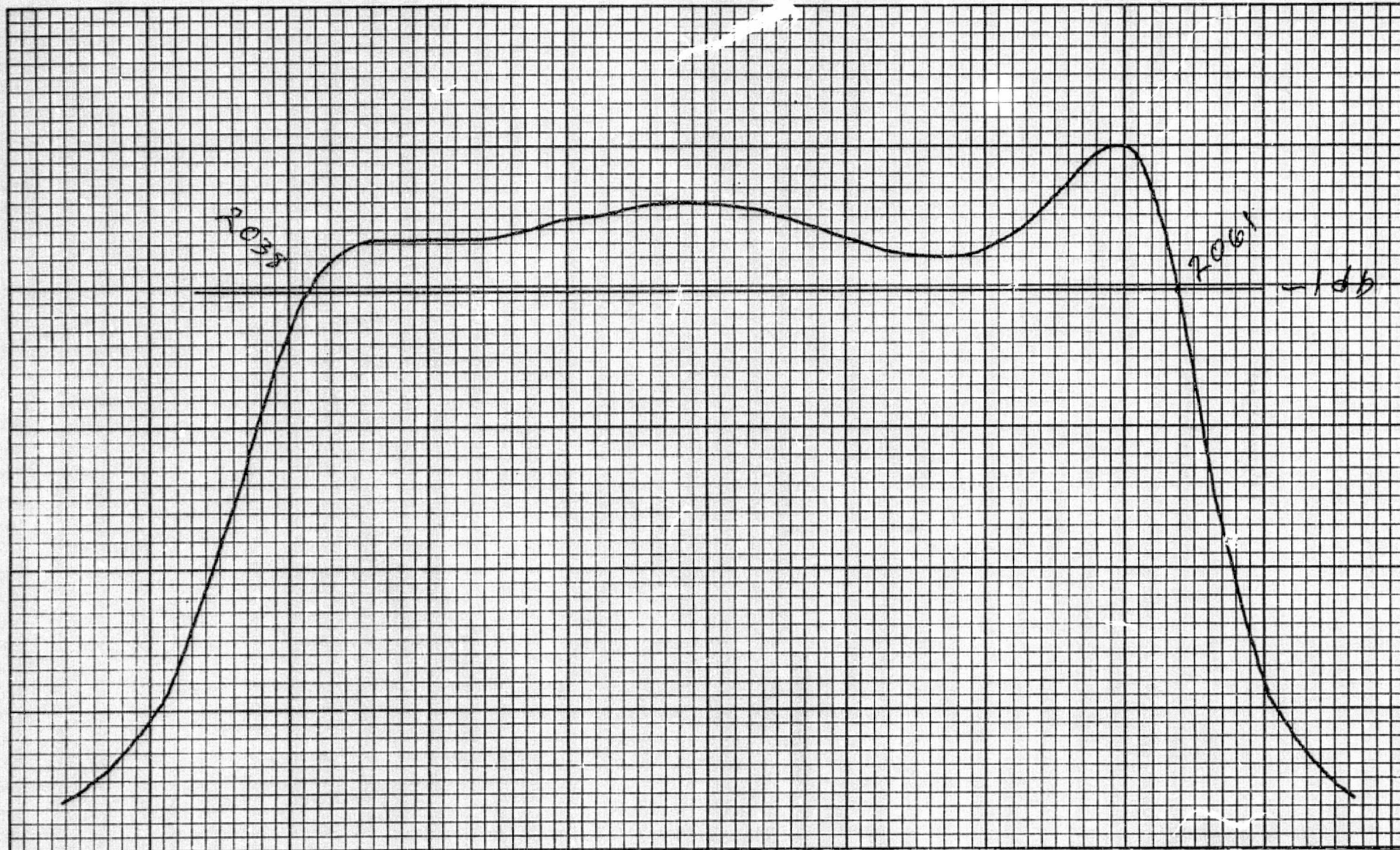
CHANNEL 2

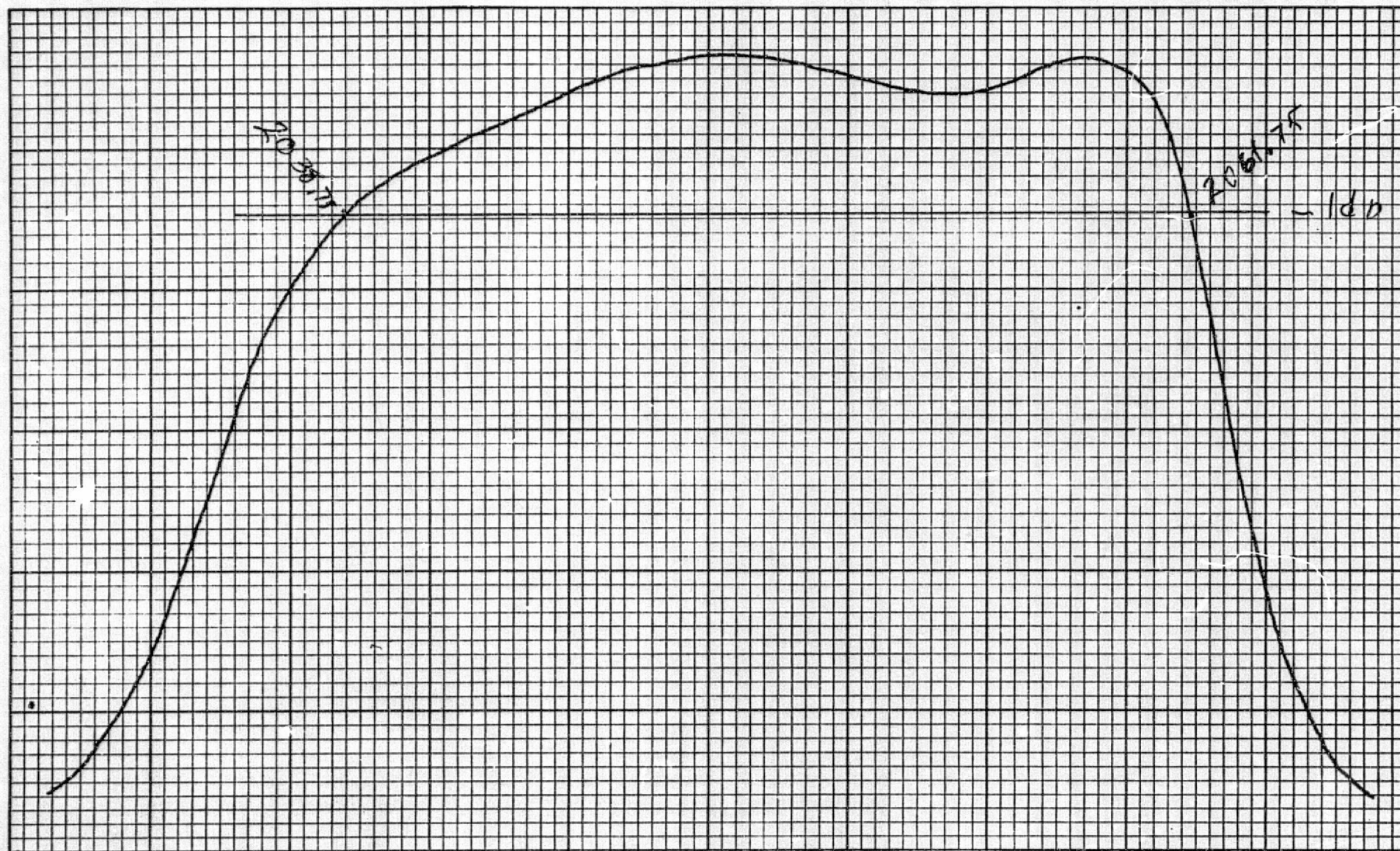
DATE: C-4-75 BY: WRB

FILAMENT VOLTAGE 7.5 V
 FILAMENT CURRENT 10.6 A
 MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV
 BEAM CURRENT 2.6 A
 BODY CURRENT 15 mA

POWER OUTPUT 12 kW
 DRIVE POWER 96 mW
 GAIN _____ dB



SERIAL NO. 2CHANNEL 2DATE: 6-4-75 BY: WRBFILAMENT VOLTAGE 7.5 V
FILAMENT CURRENT 10.6 A
MAGNET CURRENT 16 ABEAM VOLTAGE 22 kV
BEAM CURRENT 2.6 A
BODY CURRENT 22 mAPOWER OUTPUT 24 kW
DRIVE POWER 315 mW
GAIN _____ dB

SERIAL NO. 2

CHANNEL 3

DATE: 6-4-75 BY: WRB

FILAMENT VOLTAGE 7.5 V

BEAM VOLTAGE 22 kV

POWER OUTPUT 1.2 kW

FILAMENT CURRENT 10.6 A

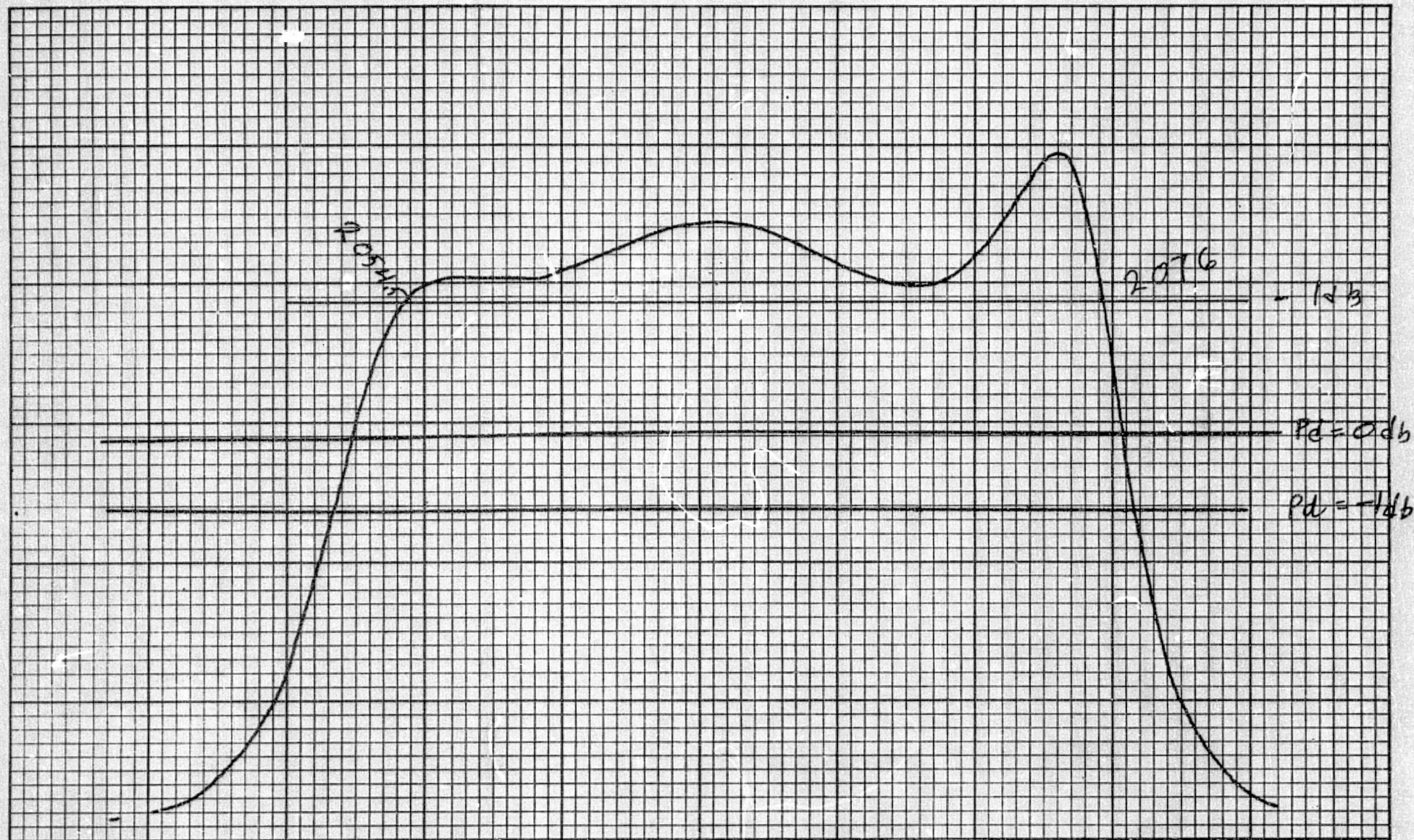
BEAM CURRENT 2.6 A

DRIVE POWER 6.4 mW

MAGNET CURRENT 16 A

BODY CURRENT 13 mA

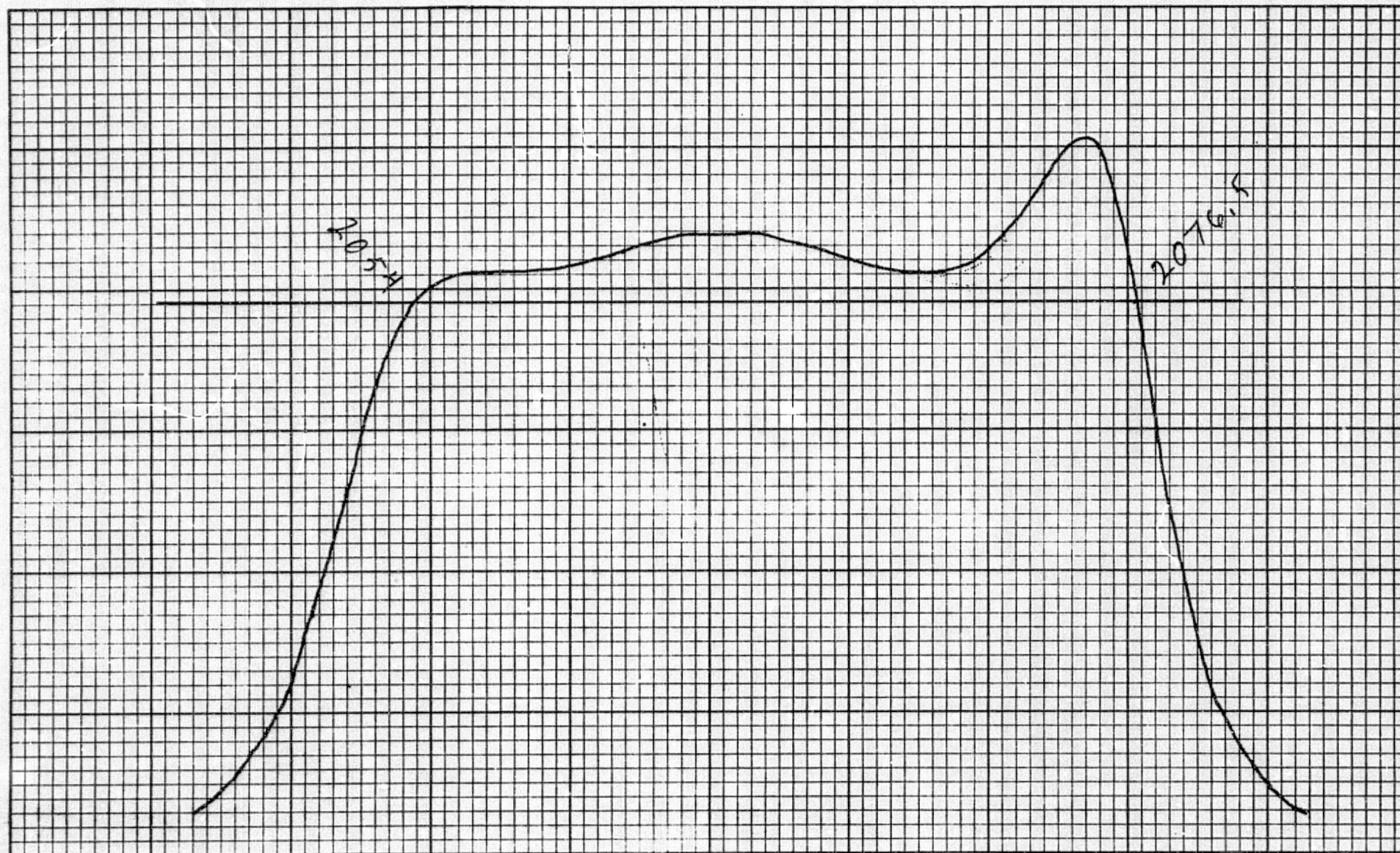
GAIN _____ dB



FREQUENCY MHz - 28 -

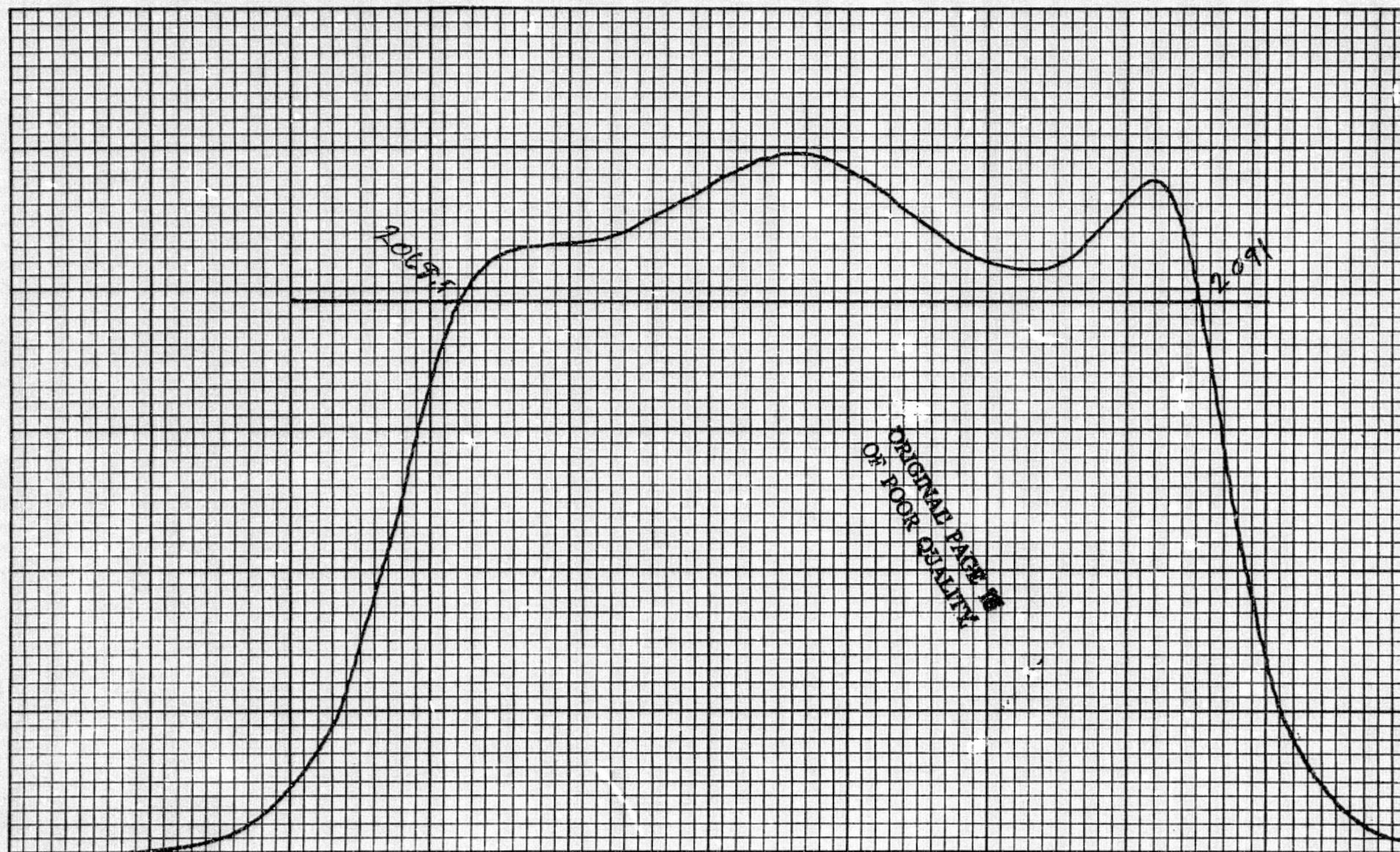
SERIAL NO. 2CHANNEL 3DATE: 6-4-75 BY: WRBFILAMENT VOLTAGE 7.5 VBEAM VOLTAGE 22 kVPOWER OUTPUT 12 kWFILAMENT CURRENT 10.6 ABEAM CURRENT 2.6 ADRIVE POWER 85 mWMAGNET CURRENT 16 ABODY CURRENT 15 mA

GAIN _____ dB

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SERIAL NO. 2CHANNEL 4DATE: 6-4-75 BY: WRBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 12 mAPOWER OUTPUT 1.2 kWDRIVE POWER 6.6 mW

GAIN _____ dB



FREQUENCY MHz

SERIAL NO. 2

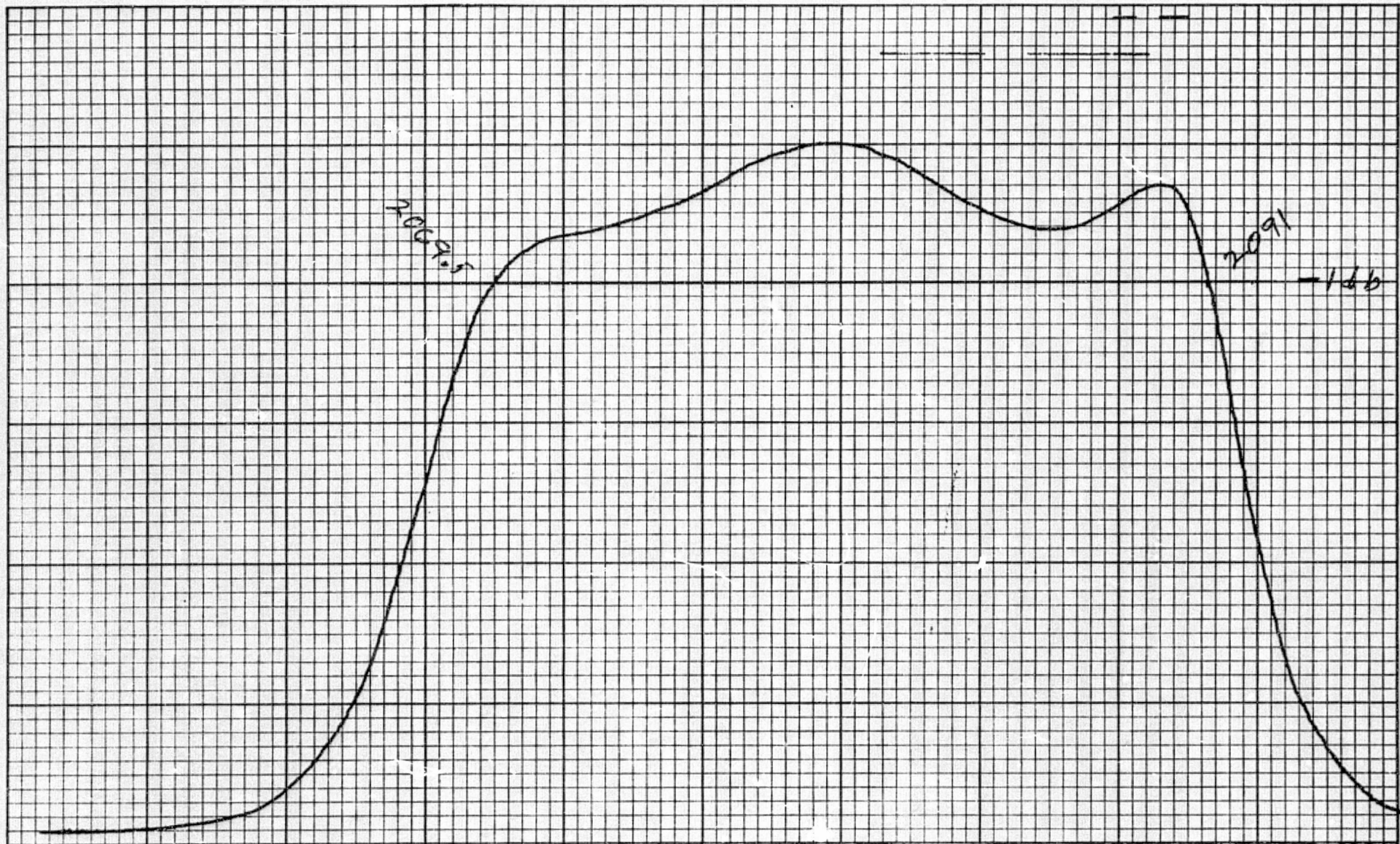
CHANNEL 4

DATE: 6-4-75 BY: WRB

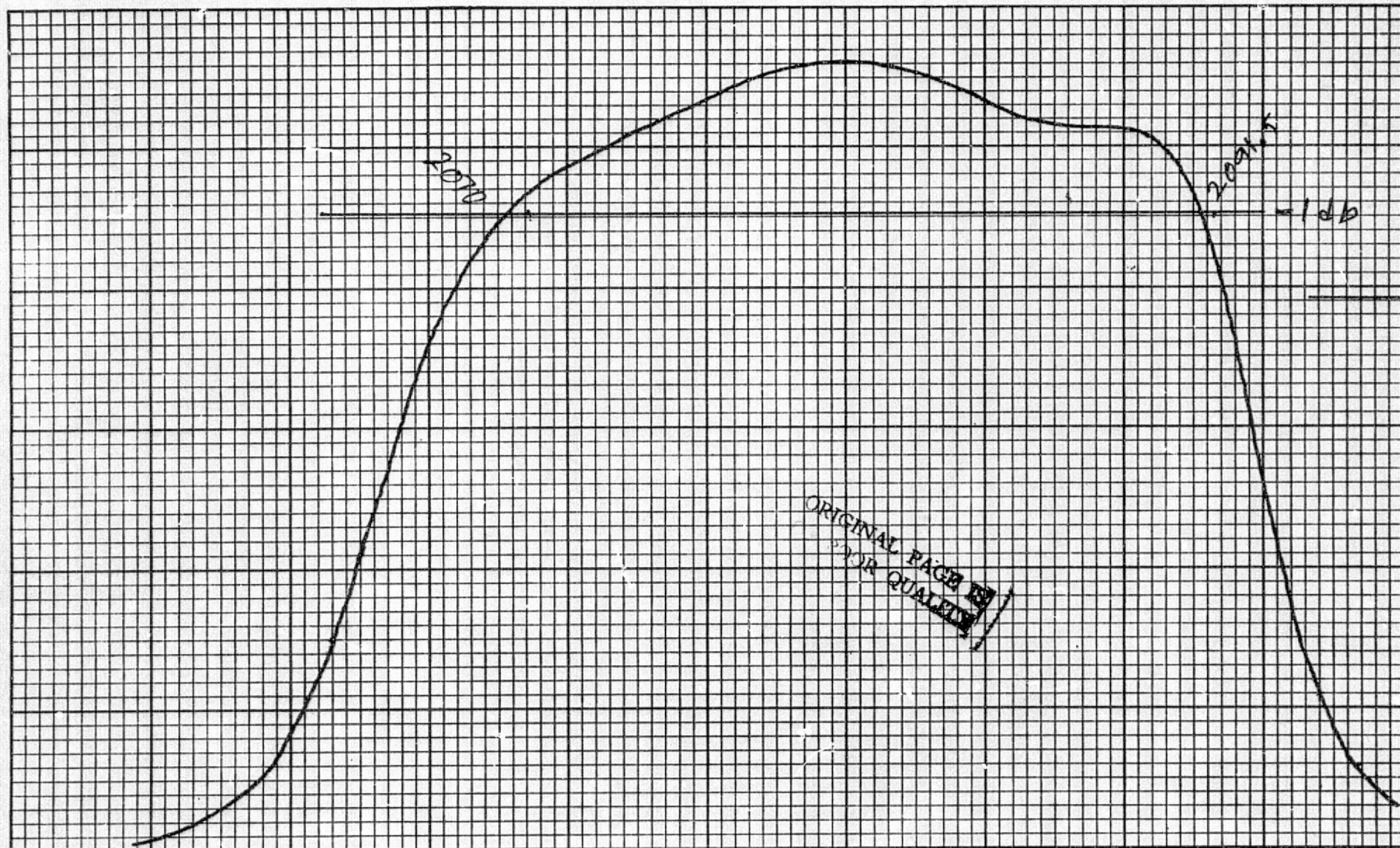
FILAMENT VOLTAGE 7.5 V
 FILAMENT CURRENT 10.6 A
 MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV
 BEAM CURRENT 2.6 A
 BODY CURRENT 18 mA

POWER OUTPUT 12 kW
 DRIVE POWER 85 mW
 GAIN _____ dB



FREQUENCY MHz - 28 -

SERIAL NO. 2CHANNEL 4DATE: 6-4-75 BY: WRBFILAMENT VOLTAGE 7.5 V
FILAMENT CURRENT 10.6 A
MAGNET CURRENT 16 ABEAM VOLTAGE 22 kV
BEAM CURRENT 2.6 A
BODY CURRENT 30 mAPOWER OUTPUT 24 kW
DRIVE POWER 285 mW
GAIN _____ dB

FREQUENCY MHz

- 28 -

SERIAL NO. 2

CHANNEL 5

DATE: 6-4-75 BY: W/RB

FILAMENT VOLTAGE 7.5 V

BEAM VOLTAGE 22 kV

POWER OUTPUT 1.2 kW

FILAMENT CURRENT 10.6 A

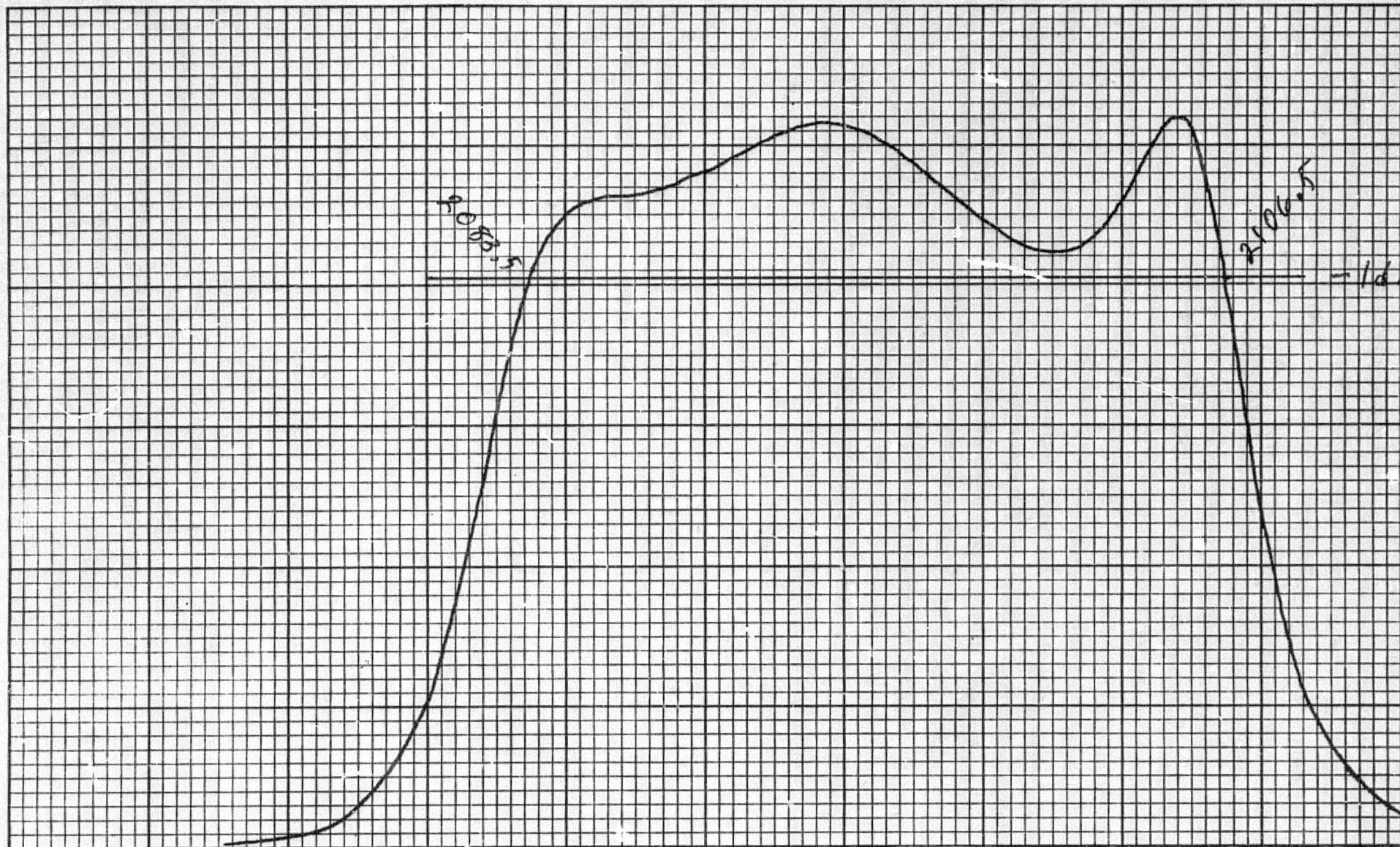
BEAM CURRENT 2.6 A

DRIVE POWER 5.35 mW

MAGNET CURRENT 16 A

BODY CURRENT 12 mA

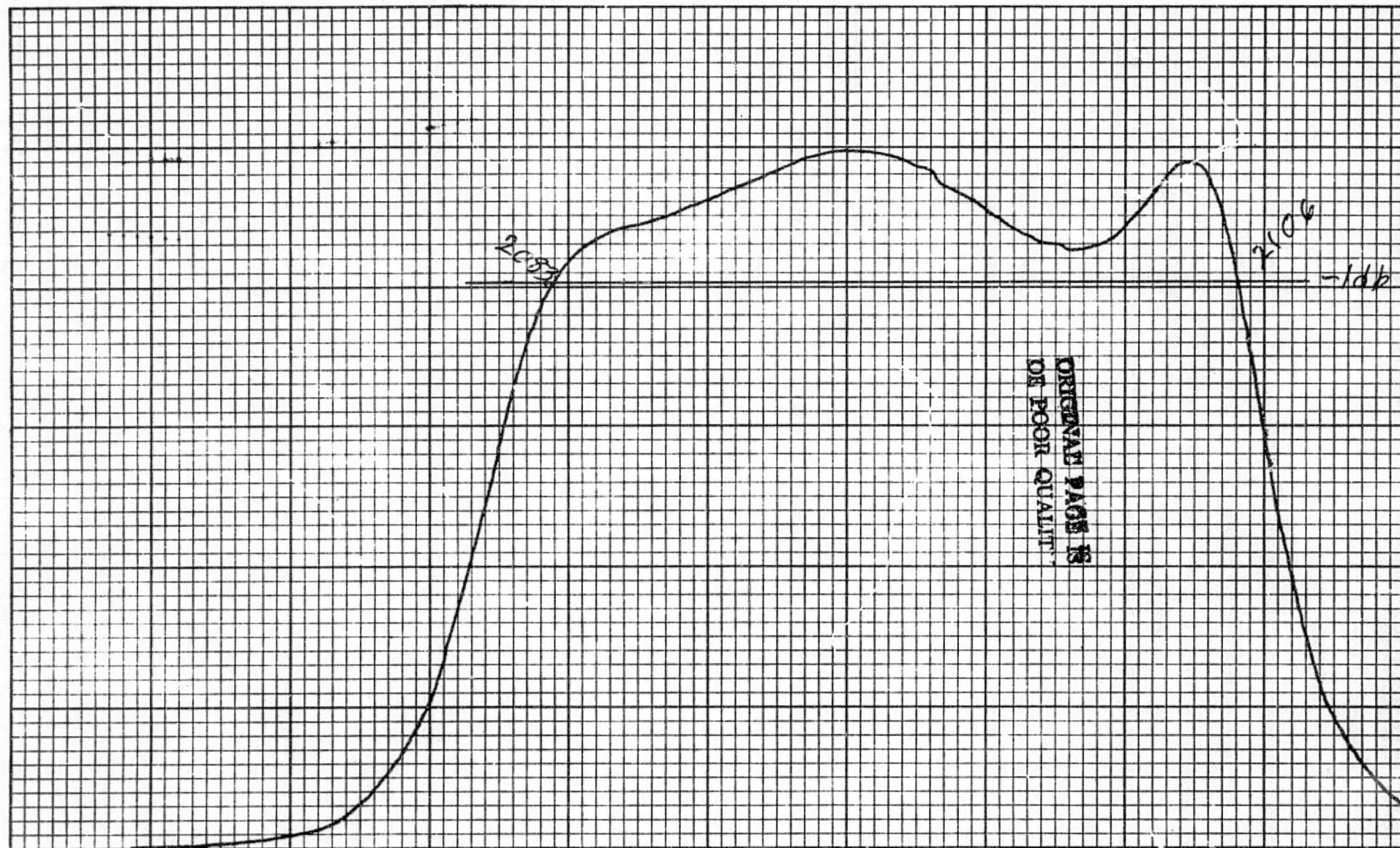
GAIN _____ dB



FREQUENCY MHz - 28 -

SERIAL NO. 2CHANNEL 5DATE: 6-4-75 BY: WRBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 10.6 AMAGNET CURRENT 16. ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 18 mAPOWER OUTPUT 12 kWDRIVE POWER 70 mW

GAIN _____ dB



FREQUENCY MHz

SERIAL NO. 2

CHANNEL 5

DATE: 6-4-75 BY: WRB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

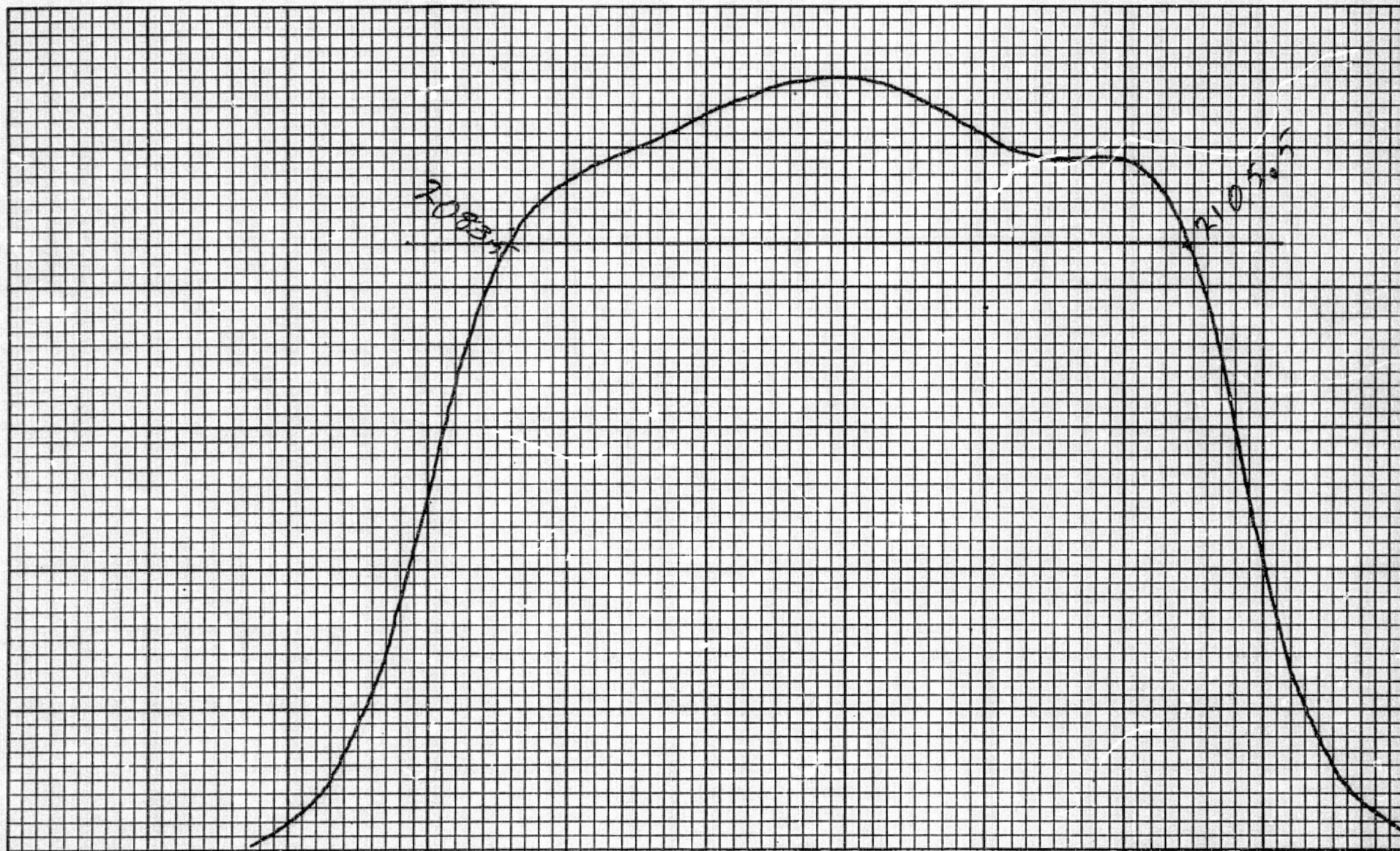
BEAM CURRENT 2.6 A

BODY CURRENT 3.3 mA

POWER OUTPUT 24 kW

DRIVE POWER 200 mV

GAIN _____ dB

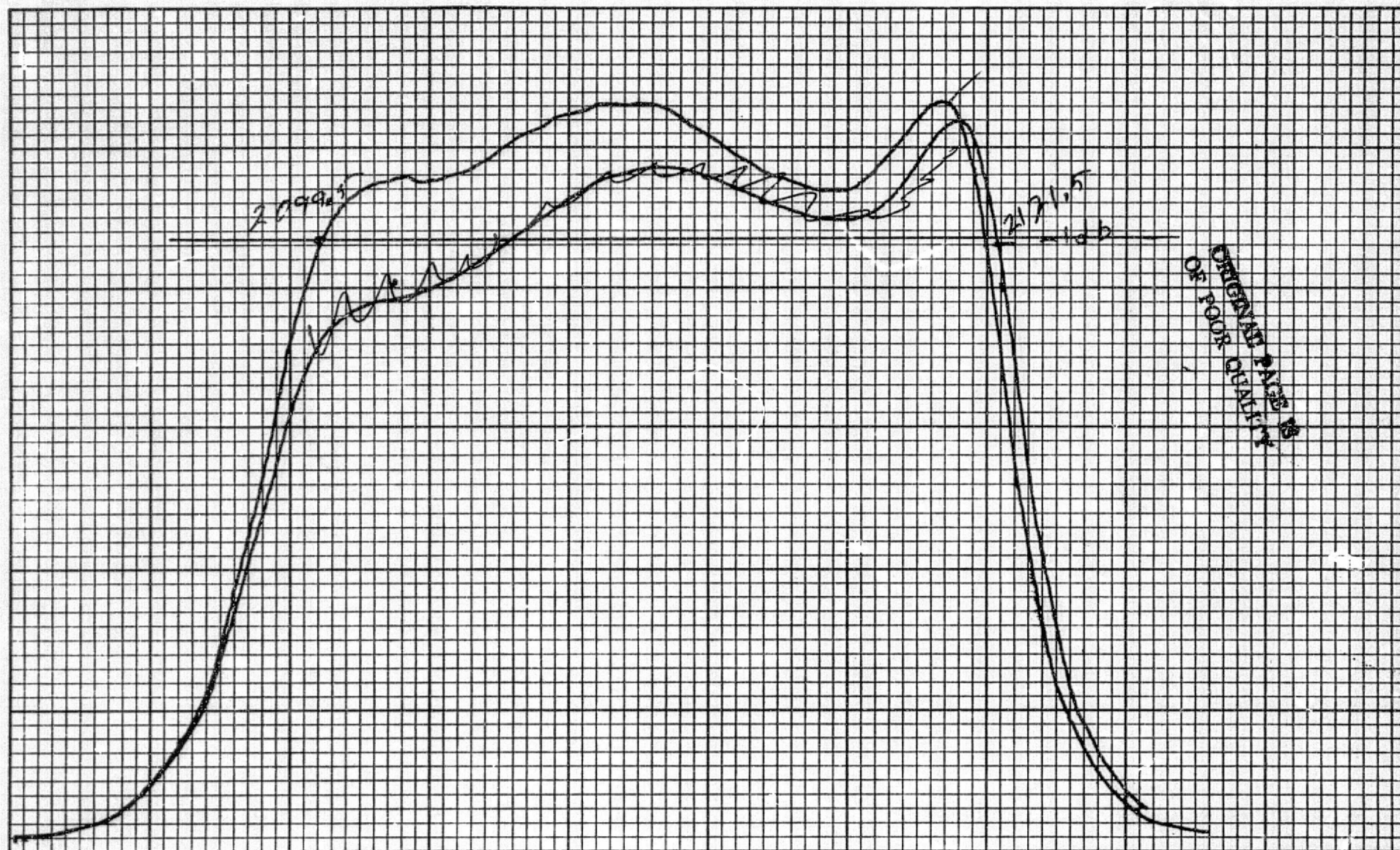


FREQUENCY MHz

- 28 -

SERIAL NO. 2CHANNEL 6DATE: C-4-75 BY: WRBFILAMENT VOLTAGE 7.5 VFILAMENT CURRENT 15.6 AMAGNET CURRENT 16 ABEAM VOLTAGE 22 kVBEAM CURRENT 2.6 ABODY CURRENT 12 mAPOWER OUTPUT 1.2 kWDRIVE POWER 7.5 mW

GAIN _____ dB



FREQUENCY MHz

- 28 -

SERIAL NO. 2

CHANNEL 6

DATE: 6-4-75 BY: WRB

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

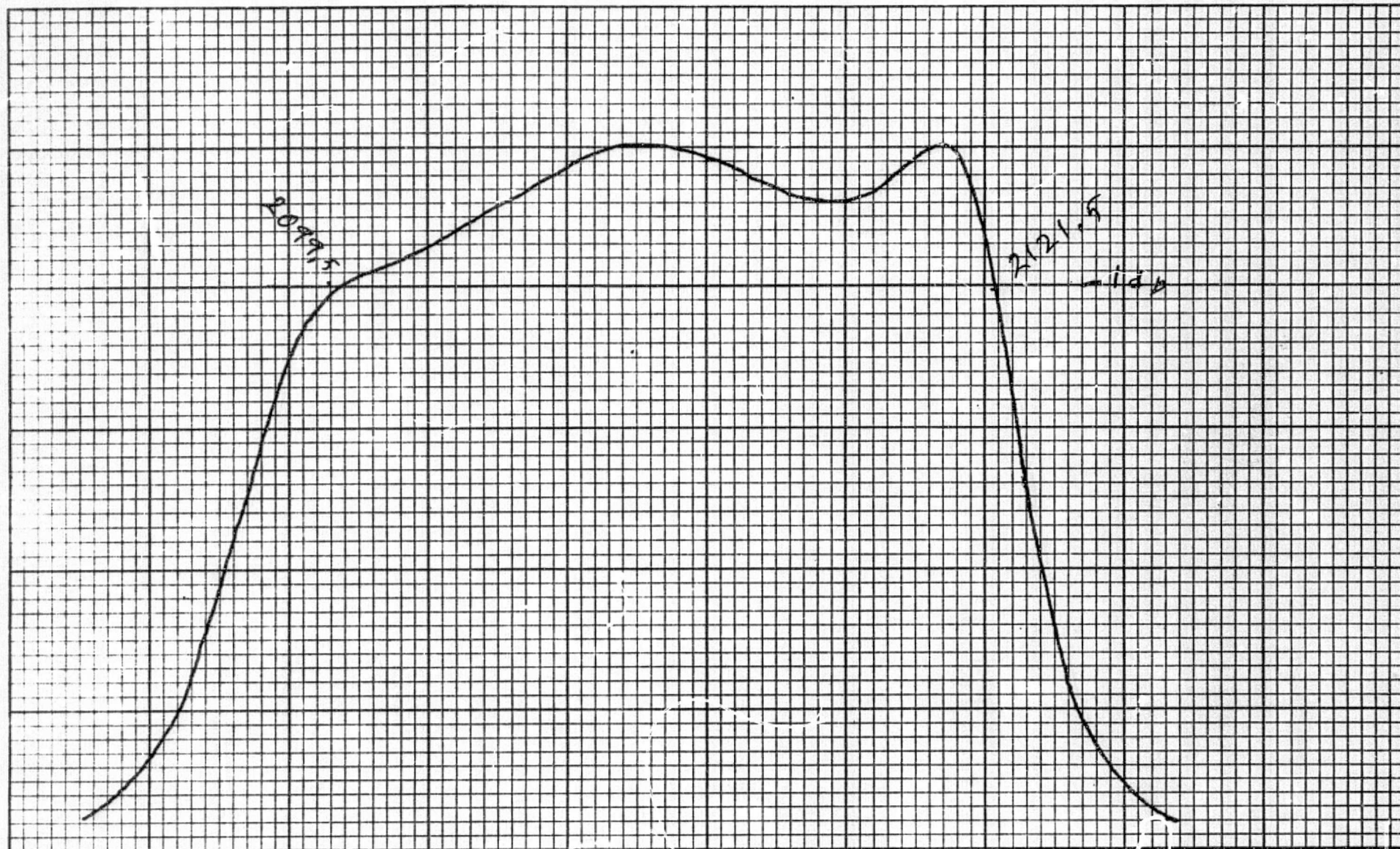
BEAM CURRENT 2.6 A

BODY CURRENT 18 mA

POWER OUTPUT 12 kW

DRIVE POWER 120 mW

GAIN _____ dB



FREQUENCY MHz

- 28 -

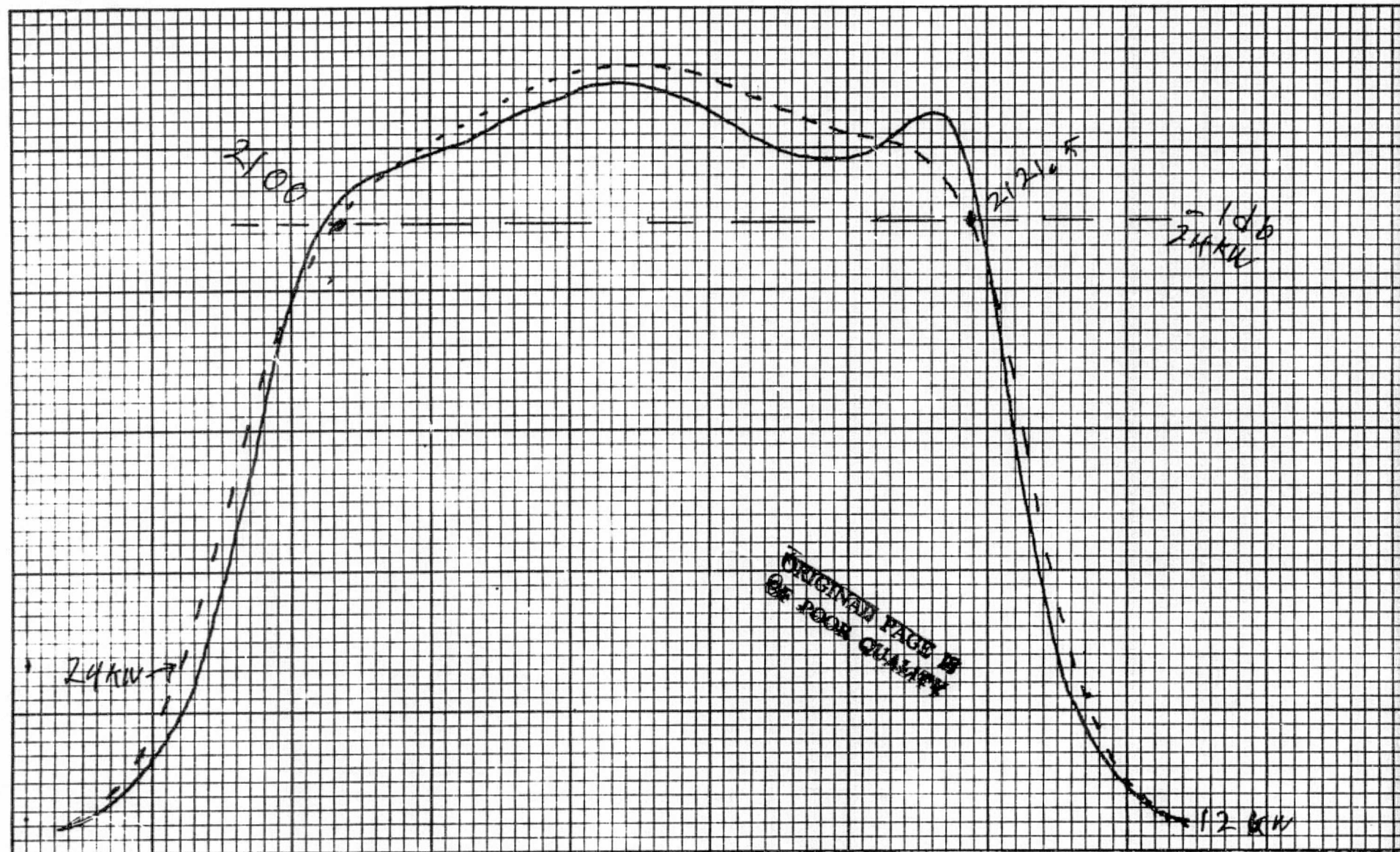
SERIAL NO. 2CHANNEL 6DATE: 6-4-75 BY: WRBFILAMENT VOLTAGE 7.5 VBEAM VOLTAGE 22 kVPOWER OUTPUT 12 WFILAMENT CURRENT 10.6 ABEAM CURRENT 2.6 A

DRIVE POWER _____ mW

MAGNET CURRENT 16 A

BODY CURRENT _____ mA

GAIN _____ dB



SERIAL NO. 2

CHANNEL 6

DATE: 6-4-75 BY: W R B

FILAMENT VOLTAGE 7.5 V

FILAMENT CURRENT 10.6 A

MAGNET CURRENT 16 A

BEAM VOLTAGE 22 kV

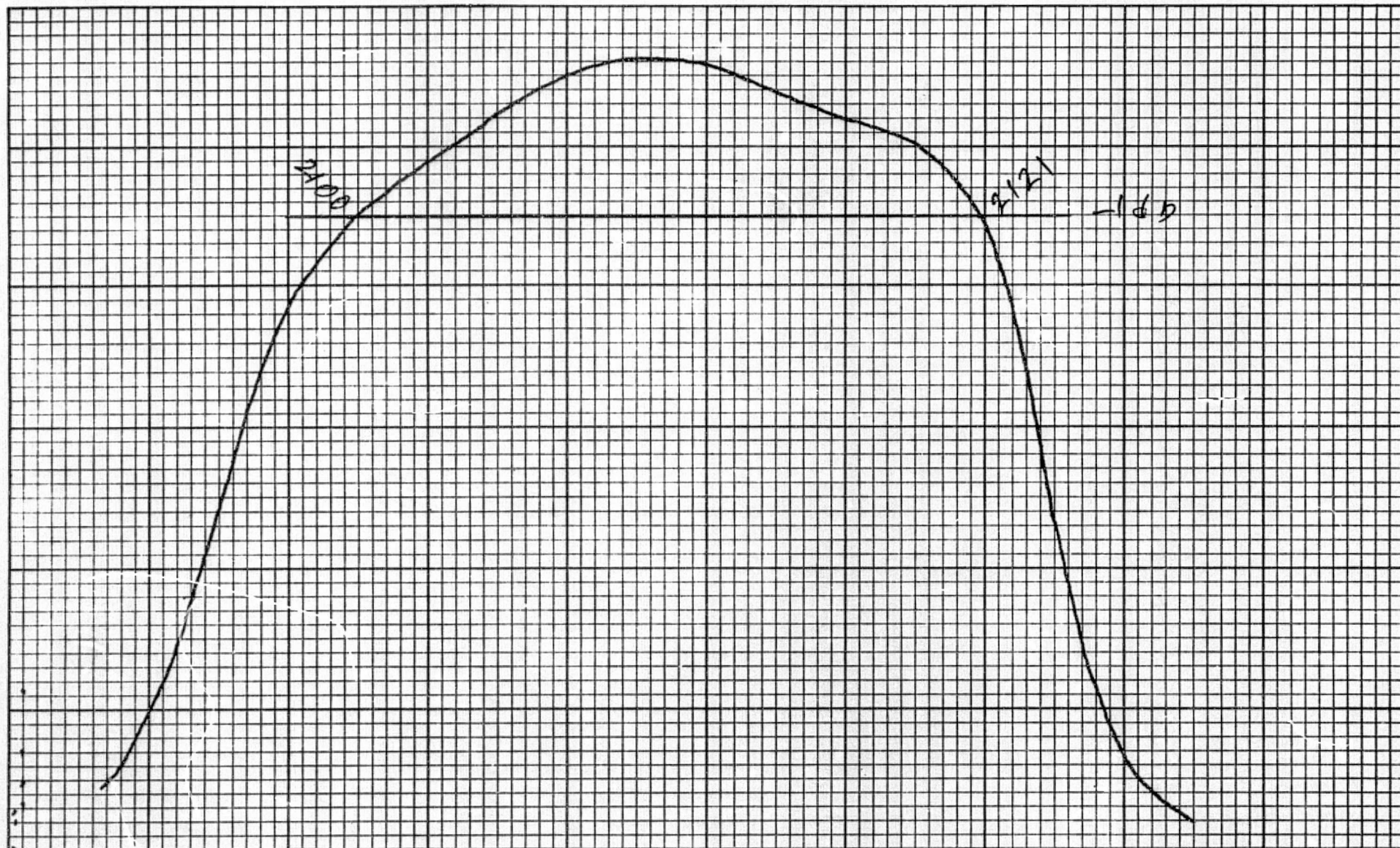
BEAM CURRENT 2.6 A

BODY CURRENT 32 mA

POWER OUTPUT 24 kW

DRIVE POWER 405 mW

GAIN _____ dB



FREQUENCY MHz - 28 -

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REMOTE TUNER
SERIAL NUMBER 52001

TUBE TYPE 5K70SK-WBT
TUBE SERIAL NO. 2

CAVITY A B C D E
ZERO INDEX 6 5 5 2 6 TURNS
FROM CLOCKWISE STOP

		STEP TUNER THUMBWHEEL SETTING				
CAVITY		A	B	C	D	E
CHANNEL	1	221	195	196	211	179
	2	311	231	295	338	271
	3	391	316	401	460	381
	4	460	423	497	570	484
	5	520	453	580	663	568
	6	592	620	663	754	656
758*						

*Changed on 4 June 1975 to raise lower end of bandpass.
Slightly out of specification. See curves.

DESIGN VERIFICATION TEST PLAN

KLYSTRON STEP TUNER
MODEL 8191A

LTR	ECO 044-	DATE	APP

REVISIONS

	D W N	//
	C K D	//
	A P P	//
	A P P	//
USED ON		

SUMMIT
ENGINEERING
CORPORATION

DESIGN VERIFICATION TEST PLAN
Model 8191A

SIZE	CODE	IDENT	07	218	191	01	REV	SHEET
		33399						1/18

000-000 30

TABLE OF CONTENTS

1.0	PURPOSE	Page 3
2.0	TEST PROCEDURES	3
2.1	Load Torque Adjustment	3
2.2	Shaft Angle Position Measurement	3
3.0	TEST	4
3.1	Equipment Used for Measurements	4
3.2	Description of Tests	4
3.3	Test Set-Up	4
4.0	DATA	4
4.1	Test #1	5
4.2	Test #2	6
4.3	Test #3	7
4.4	Test #4	8
4.5	Test #5	9
4.6	Test #6	10
4.7	Test #7	11
4.8	Test #8	12
4.9	Test #9	13
4.10	Test #10	14
4.11	Test #11	15
4.12	Test #12	16
4.13	Test #13	17
4.14	Test #14	18

000-000 26

SUMMIT ENGINEERING CORPORATION

SIZE
A

CODE IDENT
33399

07 218 - 191 01

REV

SHEET
2/18

Paragraph 1.0 - PURPOSE

It is the purpose of this test plan to verify that the Model 8191A Klystron Step Tuner will meet or exceed all of the performance requirements set forth in the "SPECIFICATION KLYSTRON STEP TUNING MECHANISM", Exhibit "C", dated 31 October 1974. These tests are designed to thoroughly demonstrate the torque, positioning accuracy, and design life capabilities of the Step Tuner. These tests will be performed on a Varian furnished test fixture.

Paragraph 2.0 - PROCEDURES

The following measurement and test procedures will be utilized throughout the Design Verification tests. All of these tests will be performed on a Varian furnished VA-1470S Klystron Simulator.

Paragraph 2.1 - Load Torque Adjustment

The Varian test fixture consists of five (5) adjustable friction brakes to simulate the five (5) klystron cavities. Each of the brakes is screwdriver adjustable from the rear of the unit. In order to adjust the proper torque at each brake, loosen the clamp on the chain drive sprocket and attach a Waters Manufacturing, Inc., Model 940-1, Torque Watch. The Torque Watch is connected to the brake to be adjusted by a slotted adapter. After setting the Torque Watch Peak Torque Indicator to zero, rotate the appropriate shaft and adjust the peak torque to the desired ounce/inch loading by tightening or loosening the brake clamp adjustment.

Paragraph 2.2 - Shaft Angle Position Measurement

The shaft angle of any one of the five (5) tuner output shafts may be accurately measured with a rotary encoder. By removing the front panel of the test fixture, the rotary encoder may be coupled to any one of the five (5) output shafts. To set the zero reference for accurate shaft positioning indication, open unit and set red switch located on the lower right hand side on the mother board to the 'down' position. Initiate a tune cycle and all cavities will go to the 000 position and stop. Check that all '0' LED indicators on the Driver boards are on. This will set the tuner to its minimum mechanical position. Zero the Digitizer and reference zero as been established. This encoder will provide 5,000 counts per revolution of the output shaft. Each unit's digit on the thumbwheel switch assembly represents 75 counts on the Digitizer, therefore, setting 999 on the thumbwheel assembly should output through the encoder to the Digitizer 74,925 counts. Thus, each degree of shaft rotation will be represented by 14 counts on the Digital Display.

000-000 26

SUMMIT ENGINEERING
CORPORATION

SIZE
A

CODE IDENT
33399

07

218

191

01

REV

SHEET
3/18

Paragraph 3.0 - TEST

The design life test of 10,000 cycles has been broken into 14 separate tests. Test data sheets for each of the tests are included as a part of this test plan.

Paragraph 3.1 - Equipment Used for Measurements

The following tests will be controlled by a Computer Automation, Inc. computer, Model L.S.I.-2, and RCA CRT Monitor, a SUMMIT, Model 8104, Digitizer, a Disc Instruments, Inc. Rotary Encoder, Model 832A-1250-OBLP-TTL, and the VA-1470S Klystron Simulator.

Paragraph 3.2 - Description of Tests

The computer cycles the Model 8191A Step Tuner through each Channel 1 through 6 and back to 1 in sequence. As the Model 8191A tunes into position, the encoder outputs 5,000 pulses per revolution of the tuner shaft. These pulses are fed into the Model 8104 Digitizer, counted up and outputted to the computer. The computer displays the last tune per channel in the first column of the monitor, the lowest count in the second column and the highest count per channel in the last column.

Paragraph 3.3 - Test Set-Up

- 3.3.1 Attach the encoder to one of the tuner output shafts and record its location on the test data sheet.
- 3.3.2 Loosen shaft clamp and set the torque of each cavity to 120 ounce/inch by adjusting the hose clamp on the friction brake. Then retighten the shaft clamp.
- 3.3.3 Initiate computer and begin test. Upon completion of the test, loosen shaft clamp and read torque on each cavity.
- 3.3.4 Record ending torque; Thumbwheel setting; last, lowest, and highest reading on the Monitor; and the Veeder Root counter reading. Determine + and - error in degrees by the following: $E = \frac{T - A}{14}$

where E is the error; T, the correct reading (Thumbwheel setting X 75); A, the actual reading; and 14 the number of counts per degree. Note any additional observations in the Remarks Section.

4.0 - DATA

Attached are the Test Data Sheets.

SUMMIT	ENGINEERING CORPORATION	SIZE	CODE IDENT	07	218	191	01	REV	SHEET
		A	33399						4/18

000-00026

4.1 TEST NO. 1

DATE: 26 March 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 0

ENDING CYCLE NO.: 1669

TOTAL CYCLES THIS TEST: 1669 TEST TIME: 8.3 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on B Motor

CHANNEL NO.	T/W SETTING	COUNT			ERROR IN DEGREES
		LAST	LOW	HIGH	
1	100	7,465	7,465	7,532	+2.3 -2.5
2	997	74,746	74,746	74,804	+2.1 -2.1
3	997	74,742	74,742	74,800	+1.8 -2.4
4	450	33,724	33,719	33,772	+1.6 -2.2
5	550	41,238	41,222	41,274	+1.7 -2.0
6	650	48,441	48,723	48,770	+1.4 -1.9

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 100 VR 2: 997 VR 3: 997 VR 4: 450 VR 5: 650

ENDING TORQUE (ounce/inch):

MTR A: 70 MTR B: 65 MTR C: 80 MTR D: 70 MTR E: 75

REMARKS: Witnessed by E. Green and A. Goldfinger from Varian Associates.

000-000 26

4.2 TEST NO. 2

DATE: 27 March 1975 INSPECTOR: J. W. Drain OA & C: G. W. Witmer

BEGINNING CYCLE NO.: 1670

ENDING CYCLE NO.: 2159

TOTAL CYCLES THIS TEST: 489 TEST TIME: 4 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on B Motor

CHANNEL NO.	T/W SETTING	LAST	COUNT		ERROR IN DEGREES
			LOW	HIGH	
1	999	74,895	74,885	74,924	+ 0 - 2.9
2	999	74,895	74,885	76,207	+91.5 - 2.9
3	999	74,925	74,886	74,925	+ 0 - 2.8
4	999	76,209	74,886	76,211	+91.9 - 2.8
5	999	74,894	74,888	74,925	+ 0 - 2.6
6	990	74,222	74,221	74,260	+ 0.7 - 2.1

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 990

ENDING TORQUE (ounce/inch):

MTR A: 70 MTR B: 35 MTR C: 50 MTR D: 65 MTR E: 45

REMARKS: Logic sees Ø at 999 setting and runs to mechanical stop occasionally. 999 not reliable setting.

000-000 26

4.3 TEST NO. 3.

DATE: 28 March 1975 INSPECTOR: J. W. Drain QA & C: G. V. Witmer

BEGINNING CYCLE NO.: 2160

ENDING CYCLE NO.: 2267

TOTAL CYCLES THIS TEST: 107 TEST TIME: 1 Hour (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 0

Encoder Mounted on C Motor

CHANNEL NO.	T/W SETTING	COUNT			ERROR IN DEGREES
		LAST	LOW	HIGH	
1	999	74,905	74,905	74,919	+0 -1.4
2	999	74,907	74,904	74,919	+0 -1.5
3	999	74,907	74,905	74,919	+0 -1.4
4	999	74,907	74,889	74,919	+0 -2.6
5	999	74,906	74,890	74,919	+0 -2.5
6	999	74,905	74,904	74,919	+0 -1.5

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 90 MTR B: 125 MTR C: 70 MTR D: 60 MTR E: 0

REMARKS: Testing of 250 µfd capacitors for torque would not allow running of E MTR due to size restriction.

000-000 26

4.4 TEST NO. 4

DATE: 29 March 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 2268

ENDING CYCLE NO.: 2367

TOTAL CYCLES THIS TEST: 99 TEST TIME: 1 Hour (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 0

Encoder Mounted on D Motor

CHANNEL NO.	T/W SETTING	COUNT			ERROR IN DEGREES
		LAST	LOW	HIGH	
1	999	74,956	74,926	75,356	+30.7 - 0
2	999	74,956	74,926	74,956	+ 2.2 - 0
3	999	74,956	74,926	74,956	+ 2.2 - 0
4	999	74,956	74,926	74,956	+ 2.2 - 0
5	999	74,956	74,926	74,956	+ 2.2 - 0
6	999	74,956	74,926	74,956	+ 2.2 - 0

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 90 MTR B: 40 MTR C: 70 MTR D: 60 MTR E: 0

REMARKS: E MTR not connected--see 4.3 250 µfd capacitors on Driver of DMTR.

000-000 26

4.5 TEST NO. 5

DATE: 29 March 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 2368

ENDING CYCLE NO.: 2467

TOTAL CYCLES THIS TEST: 99 TEST TIME: 1 Hour (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 0

Encoder Mounted on A Motor

CHANNEL NO.	T/W SETTING	COUNT			ERROR IN DEGREES
		LAST	LOW	HIGH	
1	999	74,921	74,900	74,921	+0 -1.8
2	999	74,904	74,900	74,921	+0 -1.8
3	999	74,904	74,901	74,921	+0 -1.7
4	999	74,921	74,902	74,921	+0 -1.6
5	999	74,921	74,901	74,921	+0 -1.7
6	999	74,921	74,903	74,921	+0 -1.6

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 120 MTR B: 80 MTR C: 60 MTR D: 85 MTR E: 0

REMARKS: E MTR not connected--see 4.3.

000-00026

4.6 TEST NO. 6

DATE: 3 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 2468

ENDING CYCLE NO.: 2674

TOTAL CYCLES THIS TEST: 206 TEST TIME: 2 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on D Motor

CHANNEL NO.	T/W SETTING	LAST	COUNT		ERROR IN DEGREES
			LOW	HIGH	
1	995	74,644	74,644	74,648	+1.6 -0
2	995	74,644	74,643	74,648	+1.6 -0
3	995	74,648	74,643	74,649	+1.7 -0
4	995	74,644	74,643	74,649	+1.7 -0
5	995	74,644	74,643	74,649	+1.7 -0
6	995	74,651	74,643	74,652	+1.9 -0

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 995 VR 2: 995 VR 3: 995 VR 4: 995 VR 5: 995

ENDING TORQUE (ounce/inch):

MTR A: 65 MTR B: 40 MTR C: 50 MTR D: 60 MTR E: 50

REMARKS: A. Goldfinger gave permission to run at 995 because of reliability problems at 999.

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SUMMIT ENGINEERING CORPORATION A CODE IDENT 33399 07 218 191 01 10/18

4.7 TEST NO. 7

DATE: 3 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 2675

ENDING CYCLE NO.: 4124

TOTAL CYCLES THIS TEST: 1449 TEST TIME: 12 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on E Motor

CHANNEL NO.	T/W SETTING	LAST	COUNT		ERROR IN DEGREES
			LOW	HIGH	
1	995	74,615	74,607	74,645	+1.4 -1.3
2	995	74,614	74,613	74,645	+1.4 -0.9
3	995	74,644	74,609	74,645	+1.4 -1.1
4	995	74,615	74,613	74,644	+1.4 -0.9
5	995	74,615	74,608	74,645	+1.4 -1.2
6	995	74,615	74,613	74,644	+1.4 -0.9

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 995 VR 2: 995 VR 3: 995 VR 4: 995 VR 5: 995

ENDING TORQUE (ounce/inch):

MTR A: 60 MTR B: 50 MTR C: 60 MTR D: 40 MTR E: 75

REMARKS:

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SUMMIT ENGINEERING CORPORATION

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4.8 TEST NO. 8

DATE: 4 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 4125

ENDING CYCLE NO.: 4826

TOTAL CYCLES THIS TEST: 701 TEST TIME: 6 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on A Motor

CHANNEL NO.	T/W SETTING	COUNT			ERROR IN DEGREES
		LAST	LOW	HIGH	
1	995	74,642	74,628	74,642	+1.2 -0
2	995	74,641	74,626	74,644	+1.4 -0
3	995	74,628	74,627	74,641	+1.1 -0
4	995	74,641	74,628	74,621	+1.1 -0
5	995	74,630	74,628	74,642	+1.2 -0
6	995	74,630	74,628	74,641	+1.1 -0

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 995 VR 2: 995 VR 3: 995 VR 4: 995 VR 5: 995

ENDING TORQUE (ounce/inch):

MTR A: 65 MTR B: 50 MTR C: 70 MTR D: 50 MTR E: 80

REMARKS:

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SUMMIT ENGINEERING CORPORATION A CODE IDENT 33399 07 218 - 191 01 REV SHEET 12/18

4.9 TEST NO. 9

DATE: 4 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 4827

ENDING CYCLE NO.: 5866

TOTAL CYCLES THIS TEST: 1039 TEST TIME: 9 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on B Motor

<u>CHANNEL NO.</u>	<u>T/</u>	<u>SETTING</u>	<u>COUNT</u>			<u>ERROR IN DEGREES</u>
			<u>LAST</u>	<u>LOW</u>	<u>HIGH</u>	
1		995	74,636	74,636	74,660	+2.5 -0
2		995	74,637	74,637	74,645	+1.4 -0
3		995	74,637	74,637	74,637	+0.9 -0
4		995	74,638	74,637	74,638	+0.9 -0
5		995	74,638	74,637	74,638	+0.9 -0
6		990	74,261	74,261	74,262	+0.9 -0

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 995 VR 2: 995 VR 3: 995 VR 4: 995 VR 5: 990

ENDING TORQUE (ounce/inch):

MTR A: 20 MTR B: 50 MTR C: 40 MTR D: 40 MTR E: 40

REMARKS: Unit's digit T/W bad in B MTR Channel 6.

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SUMMIT ENGINEERING CORPORATION

SIZE A

CODE IDENT 33399

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REV

SHEET 13/18

4.10 TEST NO. 10

DATE: 5 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 5867

ENDING CYCLE NO.: 6230

TOTAL CYCLES THIS TEST: 363 TEST TIME: 3 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 0 MTR B: 0 MTR C: 0 MTR D: 0 MTR E: 0

Encoder Mounted on C Motor

CHANNEL NO.	T/W SETTING	LAST	COUNT		ERROR IN DEGREES
			LOW	HIGH	
1	995	74,640	74,639	74,641	+1.1 -0
2	995	74,640	74,629	74,641	+1.1 -0
3	995	74,640	74,624	74,641	+1.1 -0
4	995	74,640	74,624	74,641	+1.1 -0
5	995	74,640	74,624	74,641	+1.1 -0
6	995	74,640	74,624	74,641	+1.1 -0

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 995 VR 2: 995 VR 3: 995 VR 4: 995 VR 5: 995

ENDING TORQUE (ounce/inch):

MTR A: 0 MTR B: 0 MTR C: 0 MTR D: 0 MTR E: 0

REMARKS: First Test Fixture failed. Ran system w/zero torque to check overshoot; none occurred.

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4.11 TEST NO. 11

DATE: 5 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 6231

ENDING CYCLE NO.: 6578

TOTAL CYCLES THIS TEST: 347 TEST TIME: 3 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on E Motor

CHANNEL NO.	T/W SETTING	COUNT			ERROR IN DEGREES
		LAST	LOW	HIGH	
1	999	74,917	74,911	74,918	+0 -1.0
2	999	74,917	74,917	74,918	+0 -0.6
3	999	74,918	74,917	74,918	+0 -0.6
4	999	74,917	74,911	74,918	+0 -1.0
5	999	74,917	74,915	74,918	+0 -0.7
6	999	74,917	74,916	74,918	+0 -0.6

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 70 MTR B: 80 MTR C: 65 MTR D: 70 MTR E: 70

REMARKS: New Test Fixture used for remainder of testing. New duel flag assembly installed to insure reliability at 999 setting.

000-00025

4.12 TEST NO. 12

DATE: 5 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 6579

ENDING CYCLE NO.: 8048

TOTAL CYCLES THIS TEST: 1469 TEST TIME: 12 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on D Motor

<u>CHANNEL NO.</u>	<u>T/W SETTING</u>	<u>LAST</u>	<u>COUNT</u>		<u>ERROR IN DEGREES</u>
			<u>LOW</u>	<u>HIGH</u>	
1	999	74,931	74,915	74,972	+3.4 -0.7
2	999	74,940	74,914	74,975	+3.6 -0.8
3	999	74,934	74,914	74,976	+3.6 -0.8
4	999	74,930	74,915	74,975	+3.6 -0.7
5	999	74,928	74,915	74,976	+3.6 -0.7
6	999	74,929	74,918	74,974	+3.5 -0.5

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 80 MTR B: 20 MTR C: 50 MTR D: 70 MTR E: 60

REMARKS: Speed of motors increased which reduced greatly the mechanical resonance noise.

000-000 26

4.13 TEST NO. 13

DATE: 6 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 8049

ENDING CYCLE NO.: 8715

TOTAL CYCLES THIS TEST: 666 TEST TIME: 6 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on B Motor

<u>CHANNEL NO.</u>	<u>T/W SETTING</u>	<u>LAST</u>	<u>COUNT</u>		<u>ERROR IN DEGREES</u>
			<u>LOW</u>	<u>HIGH</u>	
1	999	74,917	3	74,919	+0
2	999	74,917	3	74,919	+0
3	999	74,918	1	74,919	+0
4	999	74,917	33	74,919	+0
5	999	74,917	1	74,919	+0
6	999	74,918	9,829	74,919	+0

SEE REMARKS

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 60 MTR B: 70 MTR C: 75 MTR D: 70 MTR E: 80

REMARKS: Pin in shaft at sprocket behind knob sheared. All units at the weak point are now silver soldered.

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SUMMIT

ENGINEERING
CORPORATION

SIZE
A

CODE IDENT
33399

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SHEET

17/18

4.14 TEST NO. 14

DATE: 7 April 1975 INSPECTOR: J. W. Drain QA & C: G. W. Witmer

BEGINNING CYCLE NO.: 8,715

ENDING CYCLE NO.: 10,860

TOTAL CYCLES THIS TEST: 2145 TEST TIME: 18 Hours (approximately)

TORQUE SETTING AT START OF TEST (ounce/inch):

MTR A: 120 MTR B: 120 MTR C: 120 MTR D: 120 MTR E: 120

Encoder Mounted on C Motor

CHANNEL NO.	T/W SETTING	LAST	COUNT		ERROR IN DEGREES
			LOW	HIGH	
1	999	74,904	74,888	74,925	+0 -2.6
2	999	74,904	74,891	74,925	+0 -2.4
3	999	74,891	74,890	74,925	+0 -2.5
4	999	74,904	74,891	74,925	+0 -2.4
5	999	74,891	74,890	74,925	+0 -2.5
6	999	74,903	74,893	74,925	+0 -2.3

VEEDER ROOT COUNTER READING AT END OF TEST:

VR 1: 999 VR 2: 999 VR 3: 999 VR 4: 999 VR 5: 999

ENDING TORQUE (ounce/inch):

MTR A: 30 MTR B: 35 MTR C: 45 MTR D: 40 MTR E: 40

REMARKS:

000-00026

APPENDIX

SUPPLEMENTAL ENGINEERING INFORMATION



INTRODUCTION

The high power levels of present-day microwave tubes require careful attention to design and operation of cooling systems. In some cases, inadequate or improper cooling due to scale or corrosion may be the limiting factor in tube life. Scale is formed as a deposit upon the wetted surface of the coolant system as the result of the conversion of a coolant-soluble salt to an insoluble compound due to the chemical reaction of the various elements in the coolant, while corrosion is the result of chemical reaction products of some portion of the wetted surface itself. This bulletin discusses causes of scale and corrosion in liquid-cooled systems and recommends ways to minimize their occurrence. When cooling is not the limiting factor in tube life, the precautions and practices described below may not be required.

The recommendations given are based on a study of liquid-cooling problems conducted for Varian Associates by Stanford Research Institute and the subsequent analysis and correction of the problems in various field operating situations.

THE KLYSTRON TUBE

The high-power, liquid-cooled klystron generally is fitted with two cooling paths, one for the collector, the other for the body of the tube. Other elements of the system which are usually liquid cooled by the same heat exchange system usually include the electromagnet, focus coil, and RF dummy load, and various pieces of microwave plumbing between tube and antenna.

The coolant flow from the collector inlet fitting is redirected at the inlet manifold into numerous small paths arranged around its cylindrical periphery, rejoined in an outlet manifold, and passed out of the tube via the outlet coolant fitting. If the direction of flow is of consequence, the connections are clearly marked on the tube.

The body cooling circuit is intended to cool and thereby stabilize the operating temperature of the various microwave cavities and their frequency control elements (tuners). Again, coolant is generally led into and removed from the body of the tube thru fittings which generally are of the quick-disconnect, self-sealing type.

In some klystrons, as much as 2 kilowatts per square inch must be transmitted through the collector wall and dissipated into the coolant. Frequently the heat flux in the collector is not uniformly distributed and, at high values of heat dissipation, a small amount of scale can cause a large rise in temperature in some portion of the collector, thus greatly increasing the possibility of premature tube failure.

The fundamental factors involved in the exchange of heat between a body and its liquid cooling medium are:

1. Maximum allowable vacuum wall temperature.
In vacuum tubes using copper, this temperature should not exceed 300°C.
2. Coolant specific heat
3. Coolant boiling temperature
4. Coolant viscosity
5. Coolant velocity

It is to be noted that any collector design, when viewed from the simple calculation of coolant temperature rise versus power dissipated, is conservatively over-rated. However, in terms of internal metal temperatures, hot-spot calibration problems, and maintenance of turbulent rather than laminar flow in the coolant channels, very conservative design is called for. Cooling channel cross-sections as small as 0.025 inch by 0.050 inch are not uncommon, and the relative ease with which these channels can be plugged with foreign particulate matter must be given careful consideration.

COOLANTS

As a tube coolant, distilled water which is chemically stable and has high heat transfer capability is much to be preferred over antifreeze mixtures. If protection against low temperatures is required, draining a system or using electric water heaters during non-operating periods will avoid the problems introduced by antifreeze.

If a freezing-point depressant is necessary, a closed cooling system complete with purification loop can be used with an uninhibited solution of ethylene glycol and water as the coolant. Although inhibited glycols are more stable than uninhibited glycols when the coolant is saturated with air, field

experience has shown that present operating methods using inhibited glycols are inadequate and lead to shorter tube life. Inhibited ethylene glycol cannot be used with coolant purification systems because the inhibitor will saturate the ion exchange resin and make it useless.

Continual purification of the coolant, as described later, is often desirable whether water or antifreeze is used.

Since antifreeze mixtures have lower cooling capabilities than water, tube ratings established for water may not apply if antifreezes are used. Before using antifreezes in Varian tubes, the Field Engineering Department should be consulted for specific recommendations.

COOLING SYSTEM DESIGN

Tubing, fittings, pumps, and other material which will be in direct contact with the coolant should be selected to minimize galvanic action. Constructing the entire cooling system of a single metal is difficult; the best compromise is to use only metals at the "noble" end of the electromotive force series. The EMF differences between these metals and the copper collector are small. Included in this group are copper, nickel, and such alloys as bronze, Monel, Inconel, 304L stainless, and 347 stainless for welded parts. Metals that should not be used in direct contact with the coolant include steel, cast iron, galvanized iron, aluminum, and magnesium. Brass should be used as sparingly as possible.

All-bronze or stainless steel turbine pumps are suitable for tubes requiring flows from 5 to 40 gallons per minute at pressures from 85 to 200 pounds per square inch. All-bronze or stainless centrifugal pumps are suitable for lower pressures.

Teflon-lined hoses are preferred for cooling-system use because natural or synthetic rubbers tend to deteriorate when used with hot liquids. If electrical insulation is required (a frequent case), they should be fabric covered; otherwise, metal armor may be used.

The cooling system should, in most cases, include means to continuously purify the coolant. This can be a purification loop which processes a small amount of coolant from the main recirculating loop by removal of soluble salts by ion-exchange, dissolved oxygen and carbon dioxide, small particulate matter, and other contaminants. If a mixture of ethylene glycol and water is to be used, provision must also be made for the removal of organic breakdown products of the glycol. Packaged purification systems suitable for this purpose are available.*

Figure 1 shows a typical arrangement of a klystron recirculating cooling system with a purification loop. In general, a single replaceable cartridge supplies the filtering, ion-exchange oxygen removal, and organic removal functions. The system also includes flow and pressure adjusting valves, flow meter, and the necessary conductivity cells and electronics for evaluation of the conditions of the filter cartridge with respect to metal ion capture.

As stated before, the filter cartridges and filter membranes are replaceable, and the size of the purification system and its operation should be in accordance with the manufacturer's recommendation.

Referring again to Figure 1, the main cooling loop shows particulate filtering (10 to 50 micron size) between the accumulator tank and pump and filtering beyond the parallel branching paths to the various circuits (represented in Figure 1 by the collector and body paths in the tube). Ingoing and return bulk coolant temperature is also monitored. Pressure measurement is indicated at the pump head and *directly* across the collector for reasons to be discussed later. The collector flow rate should be continuously monitored. Many systems also include the control equipment for maintaining the ingoing coolant temperature at a preset point, independent of seasonal changes of ambient temperature.

COOLING SYSTEM OPERATION

All contaminants such as oils, greases, and particulate matter should be removed from the system since they may deposit on the heat-exchange surfaces inside the tube and reduce the heat transfer capability. The cooling loop should, therefore, be degreased with a solvent or detergent, followed by a number of clean water flushings. Also, no soluble oil inhibitors or stop-leak compounds should be added to the coolant, since detergents, soluble oils, etc., may cause foaming.

In an installation being put into operation for the first time, special precautions must be taken to remove pipe compound, solder salts, teflon pipe-tape thread seal, bits of solder, etc., etc. With all the main cooling loop filters in place but with tube, magnet, and other components replaced with jumpering connections, thorough flushing procedures as described above should be carried out. Then, after cleaning and replacing filters, the system with tube and other components in place, can be operated in the normal mode.

The area of maintenance of purity in an operating system is very sensitive if long tube life is to be attained. Manufacturers of purifying equipment

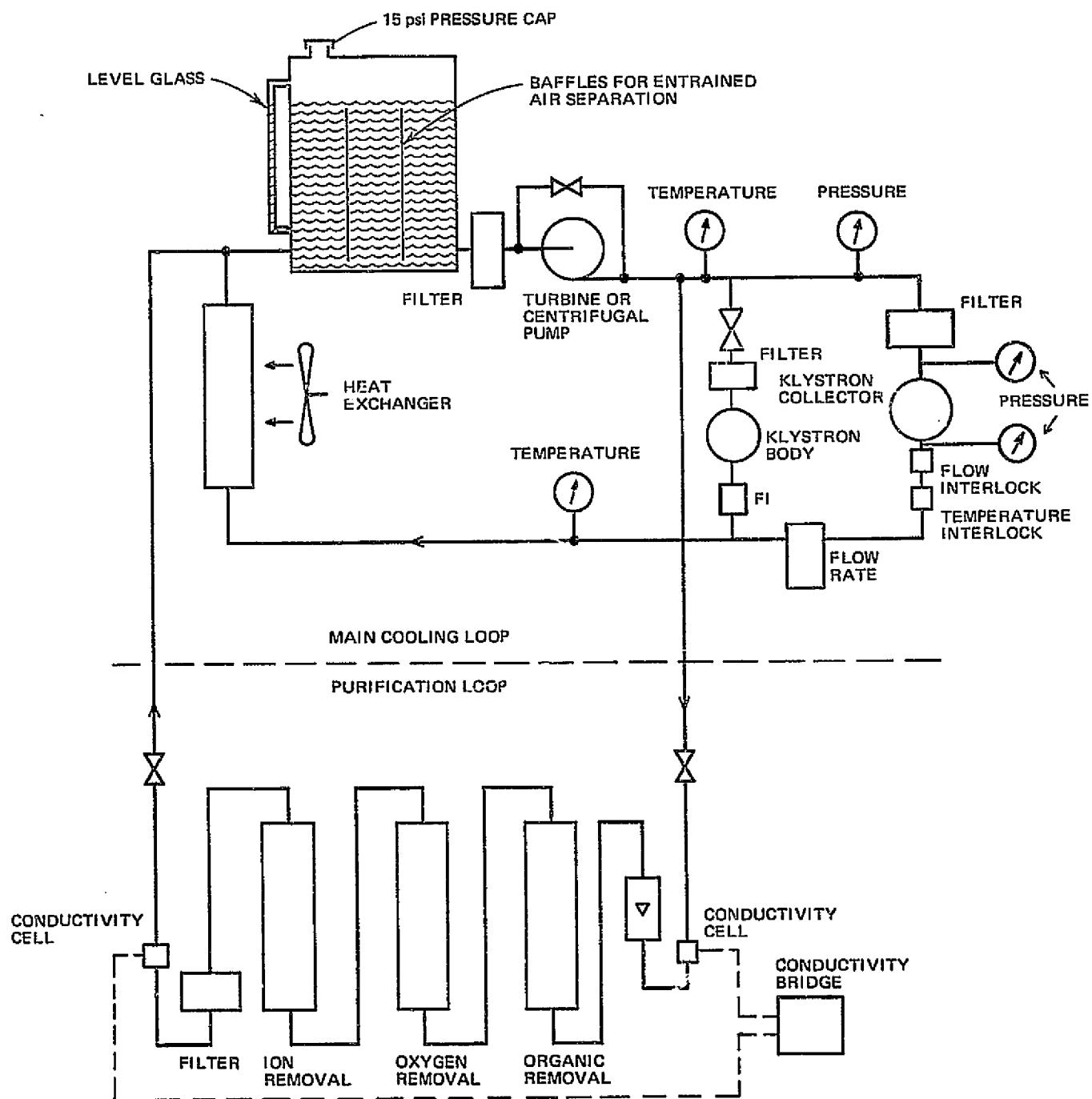


Figure 1. KLYSTRON COOLING SYSTEM WITH PURIFICATION LOOP

normally include as part of their package, a method of monitoring the resistivity of the coolant, which measures the ion content and other conductive foreign matter. Ion removal cartridge replacement is indicated when the coolant leaving the purification system falls below 1 megohm resistivity. A fresh cartridge at recommended throughput will provide 10 to 14 megohm coolant back into the main loop for 2 megohm intake resistance. Rapid exhaustion of the ion-exchange cartridge may indicate a source of contamination, electrolysis, the use of inhibited glycol, or that the purification loop lacks sufficient capacity for the bulk coolant being processed. Membranes in the submicron filter of the purification loop should be replaced when the pressure drop across the loop becomes excessive.

In the matter of *corrosion* effects in the coolant system, two sources can be recognized, namely the deterioration of piping, manifolding, and radiator due to electrolysis between dissimilar metals already mentioned previously, and the oxidation of copper material of the tube itself in the areas of high heat transfer to the coolant, primarily in the collector. The corrosion rate is directly related to the amount of dissolved oxygen in the coolant, and the temperature of the copper collector core; i.e., the collector power dissipation. In a system operating at atmospheric pressure at the accumulator tank and with no special pains taken to close the system from the atmosphere, it is common to measure 3.5 to 5 parts per million of dissolved oxygen in the coolant. It should also be recognized that it is possible to aspirate air into a closed coolant circuit at the pump rotary seal and at quick-disconnect fittings, even without evidence of liquid leakage at these points. Aspiration of air into the system will result in rapid depletion of oxygen removal chemicals without indication of a change in resistance of the coolant. Corrosion-free operation can only be attained by holding the dissolved oxygen level to 1.25 parts per million or less. This means that measurements for oxygen-level must be made frequently.

One alternative to the relatively expensive design and maintenance problems associated with tight control of oxygen in the system would be to institute flushing procedures for the tube which can be done on a routine maintenance schedule. Figure 1 includes pressure gages at the inlet and outlet ports of the collector, as well as a flow rate meter in the collector branch. Collector corrosion effects are indicated as a slowly increasing pressure differential across the collector, as the flow rate is held constant by branch valve adjustment. Thus, when the pressure drop across the collector has increased by

20–25% above that pressure value when the tube was first installed, the tube should be removed, and the corrosion products (mainly copper oxide, CuO) can be flushed out or dissolved out of the cooling channels by means of dilute hydrochloric acid, followed by a neutralizing flush and then tap water flushing. It is especially important that flushing procedures be instituted before any of the cooling channels inside the tube become so full of the corrosion products as to block the flow of the flushing liquid completely. To this end, it is strongly recommended that collector flow and pressure instrumentation be a permanent part of the coolant system installation. Specific recommendations for the flushing solution and technique are available through the Varian Tube Division Field Engineering Department.

The manufacturer's recommendation should, of course, be followed in the matter of maintenance of the cooling system as a whole; but in the interest of obtaining the longest possible tube life, the following list of adjustment and routine maintenance items are presented:

1. Keep the coolant temperature constant and as low as ambient weather conditions and other total system requirements will allow.
2. Use clean distilled water for original flushing, final filling, and make-up.
3. Use ethylene glycol only (do not use automobile radiator antifreeze).
4. Monitor the condition of the ion-exchange cartridge, recognizing that *no* knowledge of the condition of the oxygen removal portion of the cartridge is thereby gained.**
5. Keep the main loop and branch loop filters clean by routine inspection.
6. Keep the system free of dissolved oxygen or flush the tube when the collector differential pressure increases by 25% above the original value at the equivalent flow rate.
7. Follow the purification loop manufacturer's instructions with respect to replacement procedures for filter membranes and cartridges.

* One manufacturer of suitable equipment is the Barnstead Still & Sterilizer Company, 2 Louisville Terrace, Boston 31, Massachusetts.

**The Beckman Instrument Company, among others, manufactures an instrument which measures the dissolved oxygen in any liquid by a direct readout in parts per million.

INTRODUCTION

The high power levels at which klystron tubes operate require careful attention to the maintenance of water purity to assure the best possible heat dissipation. Any water containing contaminants that exceed the limits specified in this bulletin will cause corrosion and scaling. Ordinary tap water will not meet these specifications. Distilled water, however, will meet these requirements and is the recommended fluid to be used in klystron cooling systems. Periodic monitoring of water purity is necessary because the water can become contaminated by impurities from the cooling system components and from the surrounding environment. These impurities, when combined with the effects of high surface temperatures, result in a chemical reaction which causes corrosion and the formation of solids or scaling. Unchecked corrosion will attack the metals in the klystron and thus reduce its operating life. Scaling will prevent efficient heat transfer and will plug coolant passages. This will greatly increase the possibility of premature tube failure.

The recommendations given are based on a study of liquid-cooling problems conducted for Varian Associates by the Stanford Research Institute and on subsequent analyses and corrections of problems in several field operating situations.

WATER PURITY SPECIFICATION

1. The resistivity of the water shall be maintained at a level greater than $30 \text{ k}\Omega/\text{cm}^3$ at 30°C .
2. The pH factor shall be within the range of 6.0 to 8.0.
3. The particulate matter size shall not be greater than 50 microns (325 MESH).
4. The inlet water temperature shall not exceed 70°C and this temperature should be regulated to $\pm 5^\circ\text{C}$.

When the water fails to satisfy any one of these requirements, prompt action is necessary to correct these deficiencies. If the water is contaminated,

the system must be flushed and replaced with clean water. Specific recommendations are described in Application Engineering Bulletins AEB-17B and AEB-32. If the temperature of the water exceeds 70°C , the heat exchanger system should be checked or adjusted.

TESTS FOR PURITY

The recommended method for measuring resistivity, pH and particulate matter is by use of laboratory instruments. However, simple tests described here should provide enough information to determine purity.

1. *Appearance* of the water is a good general indicator. If the water looks turbid or tastes or smells brackish, it is good practice to change the water and flush the system.
2. *pH factor* is easily checked by using pH paper or Litmus paper. Sold under a variety of trade names, pH paper is available at aquarium or swimming pool equipment supply stores. Direction for use is usually printed on the packages.
3. *Particulate matter and impurities* can be checked by using the foaming test as described in Application Engineering Bulletin AEB-26.
4. *Accurate resistivity* should always be measured with a resistance bridge. Generally speaking, if the water does not pass the foaming test, the resistivity is too low.

MAINTAINING WATER PURITY

Continuous purification of the water is the recommended method for maintaining high quality water. Figure 1 shows a typical purification loop arrangement. Packaged systems such as this are available from a number of manufacturers.

In general, these systems consist of replaceable cartridges that provide the filtering, ion exchange, and organic solid removal functions. The system should include flow and pressure gauges and valves, and conductivity cells for continuous evaluation of the condition of the water and filters.

The size of the purification system should be in accordance with the manufacturer's recommendation.

An alternative to the expensive purification system would be flushing procedures which could be done on a planned maintenance schedule. The time interval between flushings would have to be adjusted to the local atmospheric conditions.

Information contained herein is furnished as a free service to users of Varian products, to aid in their maintenance or possible modification. By furnishing this information, Varian assumes no obligation or responsibility to supply parts, to pay for the cost of modifications, to exchange existing products for new production models, or otherwise.

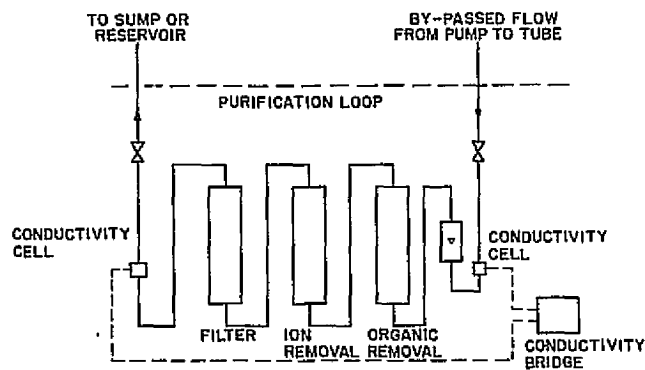


Figure 1. A Typical Purification-Loop Arrangement



VARIAN ASSOCIATES

The increasing use of doppler radar systems, both cw and pulsed, has produced considerable interest in the noise characteristics of klystron amplifiers and oscillators and the measurement of that noise. The reason that noise is important in this type of system is that it is necessary to detect and often to measure doppler shifts that produce frequencies very close to the carrier and at a power far below the carrier level. Naturally, if the klystrons (or other transmitting tubes) themselves are producing such signals, the usefulness of the radar system is thereby limited. Varian has been engaged in the production of "low-noise" (not to be confused with low noise-figure) klystrons for some time and has found it necessary to evolve special noise measuring techniques and the appropriate equipment to make the measurements. The following notes cover the high points of the noise subject. More detailed information can be supplied on specific tubes upon request.

First, some definitions must be stated to avoid ambiguity. In any discussion of noise, the bandwidth of interest must be specified. For that portion of the noise spectrum removed from the carrier by one-kilocycle or more, measurements are frequently made in a 1-kc bandwidth. For that portion of the spectrum closer than one KC from the carrier a narrow-band spectrum analyzer is used to allow investigation of noise between the discrete spectrum lines caused by power-supply ripple voltages and by 60-cycle pickup.

The defining of AM noise is a simple matter if one considers rms noise power in any bandwidth of interest. This AM noise power is usually referred to the power in the carrier with the statement that "AM noise power in a given bandwidth is a certain number of db down from the carrier".

If there is a discrete source of unwanted AM, such as could be caused by a 360-cycle ripple voltage on a power supply, this is called a

"line". The AM power in this discrete sideband is measured and again one may refer to the line as being a certain number of db down from the carrier. Since the power in discrete "lines" is usually much above the residual tube noise, the bandwidth consideration is not as important here. However, "lines" are usually measured with the minimum available bandwidth.

Since it is quite easy to make an error of either 3 or 6 db in applying this concept, an example will be given: Consider the case of an r-f wave which is amplitude modulated by a single modulating frequency. Figure 1 shows the variation of the r-f voltage with time, and Figure 2 shows the resulting r-f spectrum.

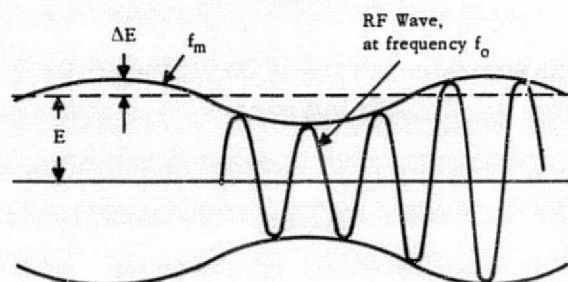


Figure 1

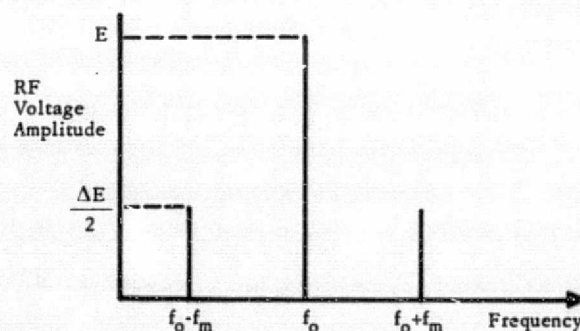


Figure 2

In these figures,

E is the average voltage of the envelope of the r-f wave, at frequency f_o . ΔE is the peak amplitude of the modulating voltage, at frequency f_m . M is the degree of modulation and is equal to $\frac{\Delta E(\text{Peak})}{E}$

The ratio of the power in the carrier to the power in one sideband is expressed:

$$\text{db} = 20 \log_{10} \frac{E}{\frac{\Delta E (\text{Peak})}{2}} \quad (\text{A})$$

If the modulation is noise, rather than sinusoidal, the signal-to-noise ratio is sometimes expressed as:

$$\text{db} = 20 \log_{10} \frac{E}{\Delta E (\text{rms})} \quad (\text{B})$$

Common mistakes arise in forgetting to properly use peak and rms numbers in the above formulas, and in not being definite in specifying whether one or both sidebands are being considered. Formulas A and B give answers differing by 3 db in the case of sinusoidal modulation, but the answers agree if both sidebands are considered (as they should be).

In general, the same concepts are used in defining and measuring FM noise and FM lines. FM noise, of course, will appear as energy at frequencies other than the carrier. It can either be "hash" or discrete sidebands, and consequently can be most easily defined in terms of noise power in a given bandwidth. In discussing FM noise one sometimes refers to "FM noise power in a given bandwidth being a certain number of db down from the unmodulated carrier". However, it is more common to refer to an "effective (or rms) frequency deviation" in the bandwidth of interest, at a certain frequency region in the spectrum. Strict definitions are required to tie these two concepts together.

Going back to the basic definition of a frequency-modulated wave which is modulated by a discrete frequency to a certain frequency deviation:

$$M_f = \frac{\Delta F}{f_m} \quad (1)$$

where M_f = modulation index in radians.

ΔF = peak deviation in cycles per second.

f_m = modulating frequency in cycles per second.

Under these conditions the first sideband will be removed from the carrier by a frequency of f_m ; the second sideband will be removed by $2 f_m$, etc. Figure 3 shows the spectrum of a frequency-modulated wave.

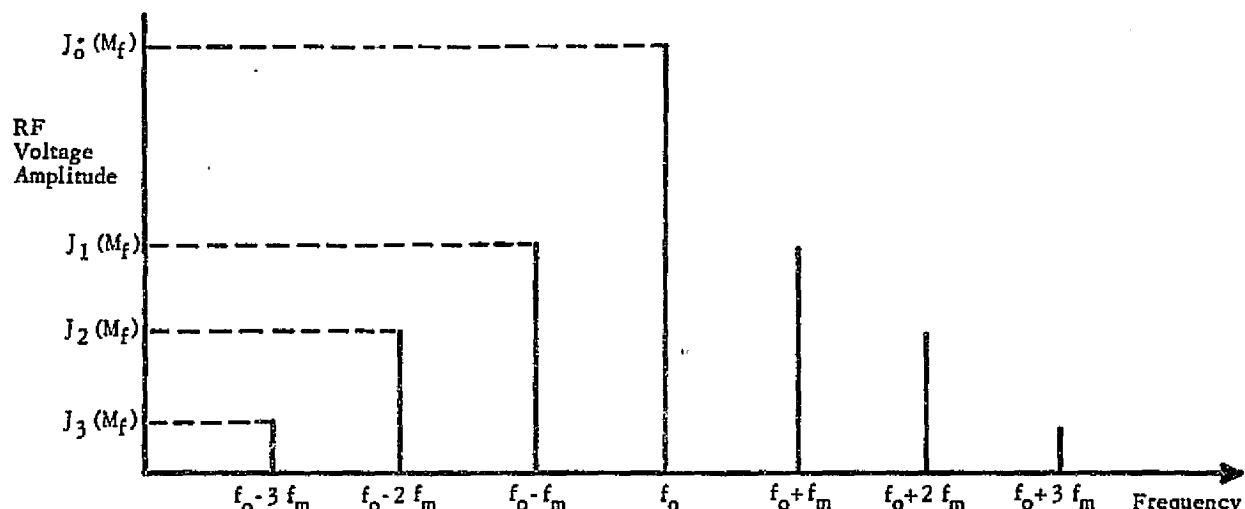


Figure 3

The amplitudes of the rf voltages in the carrier and sidebands vary as Bessel functions of the modulation index. The voltage amplitude of the carrier will vary as $J_0(M_f)$; the amplitude of the first sideband will vary as $J_1(M_f)$, etc. Therefore, the relative amplitude of the power in the carrier and the power in one of the first-order sidebands will be

$$\text{db} = 20 \log_{10} \frac{J_0(M_f)}{J_1(M_f)} \quad (2)$$

When the modulation index is small:

$$J_0(M_f) \approx 1.0, \text{ and} \quad (3)$$

$$J_1(M_f) \approx \frac{M_f}{2} \approx \frac{\Delta F}{2 f_m} \quad (4)$$

and $J_2(M_f) - - J_n(M_f)$ are negligibly small

Under these circumstances (2) becomes:

$$\text{db} = 20 \log_{10} \frac{2 f_m}{\Delta F} \quad (5)$$

Equation (5) gives the desired relationship between the power in one of the first-order sidebands and the carrier power, for small modulation indexes. It should be noted that the "db down" varies both with peak deviation (ΔF) and the distance removed from the carrier (f_m).

With this relationship it is easy to correlate a noise power measured as "so many db below the carrier", at any place in the spectrum, with an equivalent power which would be generated by a discrete modulation at the same place in the spectrum. For example:

Suppose we measure FM noise in a one-kc bandwidth centered 10 KC from the carrier and find the noise power is 100 db below the carrier power,

$$\text{Then: } 100 = 20 \log_{10} \frac{2 \times 10,000}{\Delta F}$$

solving this,

$$\Delta F = 0.2 \text{ cycles peak deviation.}$$

Consequently, the measured noise power would be the same as the power in one of the first-order sidebands which would be generated by intentionally modulating the carrier at a frequency (f_m) of 10 kc to a peak deviation of 0.2 cycles. Under these conditions, we would say the "rms frequency deviation was 0.14 the cycles per second" ($0.2 \times .707$).

A point to remember is that the power in only one of the two first-order sidebands generated by an intentional modulation has been considered. This factor may require a correction of 3 db (to include the other sideband), depending upon the actual measurement technique being used. So much for definitions.

Typically, a reflex klystron designed for low noise use, and operated on "quiet" power supplies will have an AM noise about 100-110 db below the carrier at one-KC removed from the carrier. This noise falls off to 110-120 db at 10 KC from the carrier, and is down to 120-130 db at 50 KC from the carrier. The FM "rms deviation" will be about 10-30 cycles at one KC from the carrier. It falls off gradually to about 1/2 to 1/3 of these values at 50 KC from the carrier. The above numbers are for a one-KC bandwidth, a quiet environment, and power supplies which have negligible "noise" in their output voltages at frequencies above one-KC. A typical "quiet" reflex klystron supply has peak-to-peak ripple of less than 500 microvolts, negligible voltage spikes due to switching transients, and less than 20 microvolts rms of white-noise voltage (per kilocycle bandwidth) in the beam and reflector voltage outputs.

Tubes vary greatly in their performance under vibration conditions, depending on the individual tube design and the vibration frequency and amplitude. Consequently, no "typical" data can be given. Reflex klystrons must be well isolated from variations in rf load impedance when shaken or the results will be hard to duplicate.

Varian has been very active in developing equipment for measuring very small AM and FM noise powers close to the carrier. Several different systems are available -- the complexity in general being directly related to the minimum noise to be measured. At the present time equipment has been built and used which will measure AM noise in a 1-KC band, in the spectrum from 1-KC out, to levels of 130 db below the carrier. This equipment will measure FM noise, in the same

AEB Number 11
NOISE CHARACTERISTICS
OF KLYSTRONS

bandwidth and spectrum, having an "rms deviation" as low as 0.05 cycles per second. In the spectrum from the carrier to 1-KC removed one can measure comparable AM and FM noise using a narrower bandwidth. Of course, the same equipment will also measure discrete "lines" having comparable energy content. Built-in calibration is provided for both AM and FM. While this equipment is much too complex to discuss here, inquiries are invited regarding specific noise measurement problems.

Varian has also been active in developing extremely "quiet" power supplies for both reflex klystrons and klystron power amplifiers. These supplies feature dc heaters and very low ripple and "noise" in the beam and reflector voltage outputs. These are "special" units rather than catalog items because they must usually be tailored for the individual application. Inquiries are invited on these supplies.

* * * * *

MODULATION OF KLYSTRON AMPLIFIERS DUE TO RIPPLE ON THE BEAM SUPPLY

INTRODUCTION

One of the many questions confronting the designer of a complete klystron amplifier is the degree of filtering that will be required in the high voltage beam power supply. Faced by the cost of filter inductances and condensers on one hand and by system specifications that must be met on the other hand, the designer must know what degree of ripple voltage can be tolerated.

The mechanism of the production of amplitude modulated (AM) and frequency modulated (FM) sidebands is readily understandable and equations will be derived that will enable the designer to compute the level of unwanted sidebands for known ripple voltages, or conversely, with a specified maximum level of sidebands, to compute the ripple voltage that can be tolerated.

1. AMPLITUDE MODULATION

Let us first consider the subject of generation of unwanted AM sidebands due to power supply ripple. Suppose we consider the case where the dc beam power supply has a fairly sizable amount of ripple due to insufficient filtering; let us assume that this ripple is occurring at a frequency of 360 cycles. What this means, of course, is that the beam voltage is being modulated so that it is first somewhat larger, and then somewhat smaller, than the average level. This modulation is occurring at the 360-cycle rate. Now remember that this beam voltage is being applied to the klystron, and it is causing electrons to flow through the klystron tube. When the beam voltage is higher than the average level (due to the ripple component) more electrons will be drawn from the cathode and accelerated through the tube. Furthermore, these electrons will be going somewhat "faster" than the average, due to the higher beam voltage. Therefore, the electron beam has more energy than it has on the average. Another way of stating this is that the beam supply is delivering more power to the tube, than it does on the average. If we put more dc power into the tube, it is logical to expect that we will get more rf power out of the tube. Conversely, when the power supply ripple is

causing the beam voltage to be lower than average, we will be putting less dc power into the tube than we do on the average; and we would expect the rf power to be less-than-average during this time. Therefore, it is logical to assume that the rf output would be amplitude-modulated, at the same rate as the beam voltage is being amplitude-modulated by the ripple. When we make measurements on a tube we find, indeed, that this is the case. Fortunately, this is an easy case to compute theoretically and the equation will be derived showing how large the amplitude-modulation sidebands will be (relative to the carrier) for a certain percentage beam ripple.

For the purpose of this derivation, we will make the reasonable assumption that the efficiency of the klystron will remain constant with the minor changes in beam voltage under consideration.

We will use the following notation:

V_o = dc beam voltage, in volts

ΔV_o = beam voltage ripple, (peak-to-zero)

f_m = frequency of ripple component, in cycles per second

I_o = dc beam current, in amperes

K = perveance of electron beam

η = klystron amplifier efficiency (rf power output/dc power input)

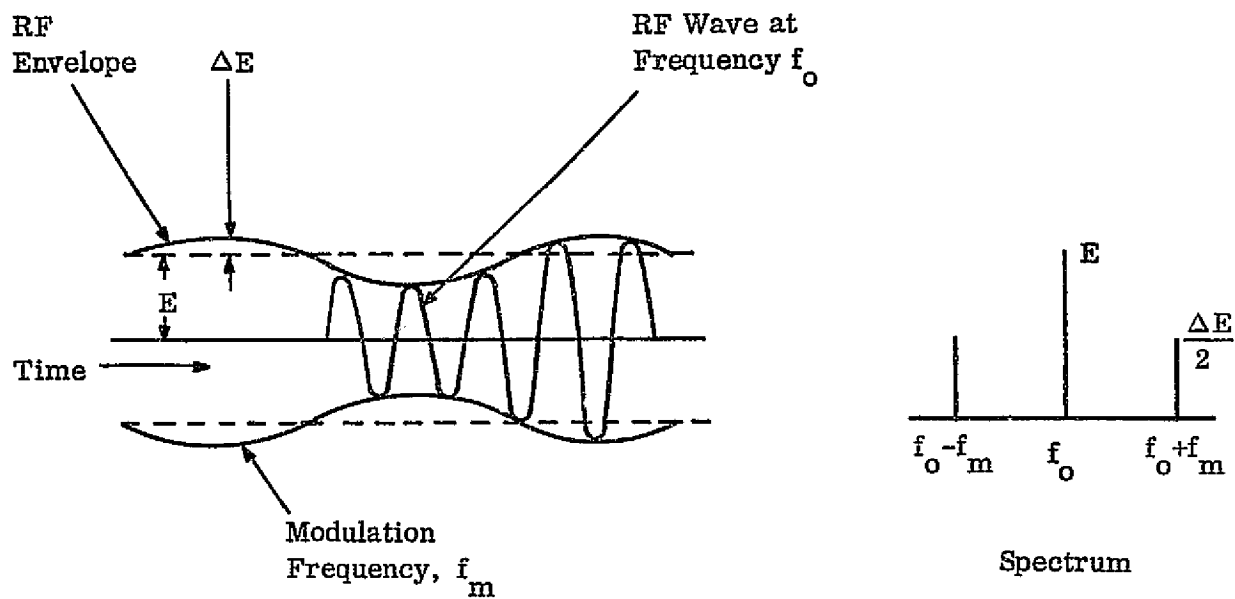
E = voltage amplitude of rf output signal (peak-to-zero)

ΔE = change in rf envelope (peak-to-zero)

f_o = rf frequency

G = conductance of the rf load

Using the nomenclature on page 2, the conventional figure for an amplitude-modulated rf signal, and its spectrum, is shown below.

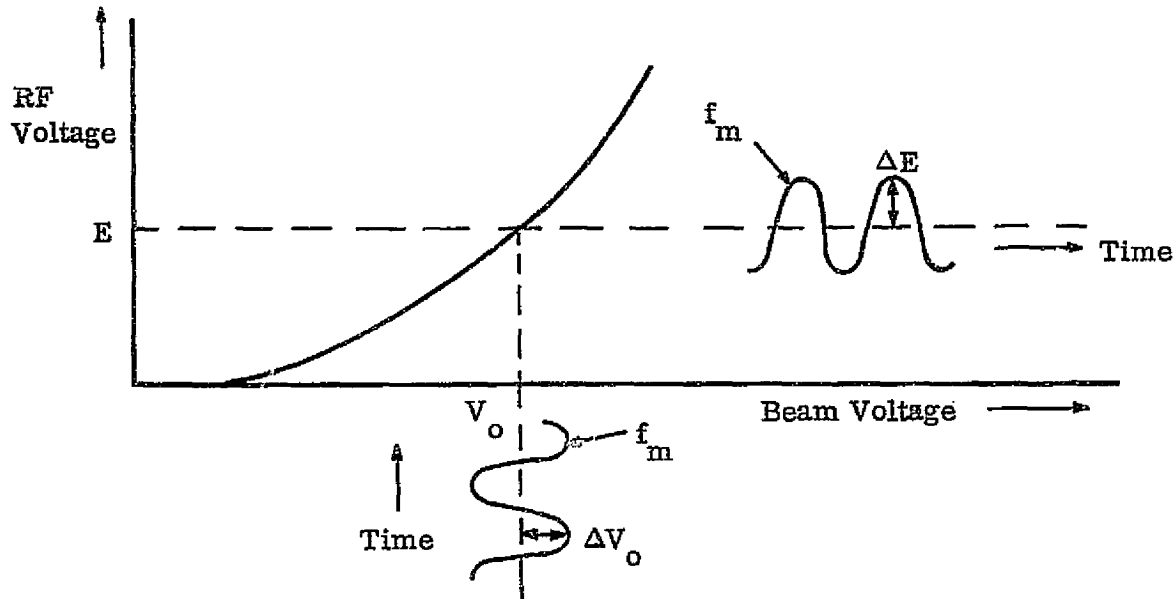


REPRESENTATION OF AMPLITUDE-MODULATED SIGNAL

The ratio of the power in the carrier to the power in one sideband in db is:

$$\frac{P_o}{P_{1SB}} \text{ (db)} = 20 \log_{10} \left(\frac{E}{\Delta E/2} \right). \quad (1)$$

The rf output from the klystron will be some function of the beam voltage, as sketched below.



EFFECT OF BEAM RIPPLE AS A FUNCTION OF TIME

E is some function of V_o ; assuming ΔV_o to be small, then:

$$\Delta E = \frac{dE}{dV_o} \Delta V_o \quad (2)$$

Now, in a klystron operating with a space-charge limited beam,

$$I_o = KV_o^{3/2} \quad (3)$$

and the dc input power is:

$$P_{dc} = V_o I_o = KV_o^{5/2} \quad (4)$$

The rf power output is:

$$P_{rf} = \frac{1}{2} GE^2 = \eta P_{dc} = \eta KV_o^{5/2} \quad (5)$$

and

$$E = \sqrt{\frac{2\eta K}{G}} V_o^{5/4} \quad (6)$$

Then

$$\frac{dE}{dV_o} = \frac{5}{4} \sqrt{\frac{2\eta K}{G}} V_o^{1/4} \quad (7)$$

Dividing (2) by $2E$, and substituting (6) and (7) gives:

$$\frac{\Delta E}{2E} = \frac{dE}{dV_o} \frac{\Delta V_o}{2E} = \frac{5}{4} \sqrt{\frac{2\eta K}{G}} V_o^{1/4} \left[\frac{\Delta V_o}{2 \sqrt{\frac{2\eta K}{G}} V_o^{5/4}} \right] = \frac{5}{8} \frac{\Delta V_o}{V_o} \quad (8)$$

Substituting (8) in (1), the ratio of power in the carrier to the power in one sideband in db is:

$$\frac{P_o}{P_{1SB}} \text{ (db)} = 20 \log_{10} \left[\frac{8}{5} \frac{V_o}{\Delta V_o} \right] \quad (9)$$

where ΔV_o is peak-to-zero ripple voltage. If ΔV_o is in rms terms, (9) becomes:

$$\frac{P_o}{P_{1SB}} \text{ (db)} = 20 \log_{10} \left[\frac{8}{5} \frac{V_o}{\sqrt{2} \Delta V_o \text{ (rms)}} \right] = 20 \log_{10} \left[1.132 \frac{V_o}{\Delta V_o \text{ (rms)}} \right] \quad (10)$$

To solve for the ratio of power in the carrier to the power in both AM sidebands, (9) becomes:

$$\frac{P_o}{P_{2SB}} \text{ (db)} = 20 \log_{10} \left[\frac{8}{5} \frac{V_o}{\sqrt{2} \Delta V_o \text{ (peak)}} \right] = 20 \log_{10} \left[1.132 \frac{V_o}{\Delta V_o \text{ (peak)}} \right] \quad (11)$$

Let us consider a typical case of a klystron operating at a beam voltage of 20,000 volts, and having a peak-to-zero ripple of 10 volts, at a ripple frequency of 360 cycles. Then:

$$\frac{P_o}{P_{2SB}} \text{ (db)} = 20 \log_{10} \left[1.132 \left(\frac{20,000}{10} \right) \right] = 67 \text{ db} .$$

Therefore the sum of the power in both sidebands is 67 db below the power in the carrier; the individual sidebands are 70 db below carrier level and are located at $f_o \pm 360$ cycles.

From the same equation it follows that if the equipment specifications require the sideband power to be 77 db below carrier at each of the sideband frequencies, the peak-to-zero ripple must be held to 1 volt.

In terms of rms ripple voltage (11) becomes:

$$\frac{P_o}{P_{2SB}} \text{ (db)} = 20 \log_{10} \left[1.132 \frac{V_o}{\sqrt{2} \Delta V_o \text{ (rms)}} \right] = 20 \log_{10} \left[0.8 \frac{V_o}{\Delta V_o \text{ (rms)}} \right] . \quad (12)$$

This equation is applicable for any ripple frequency appearing in the beam supply voltage, and for frequencies other than harmonics of the power source frequency; i.e., any ripple components that might be introduced in a beam supply voltage regulator circuit.

2. PHASE MODULATION

Now let us consider an effect on the rf output of the klystron amplifier, which is called "incidental phase-modulation." Again let us consider the case where the beam voltage is being amplitude-modulated by 360-cycle ripple. Since the beam voltage varies above, and below, the average value, the electrons passing through the tube will either be going faster or slower than the average, depending on the instantaneous beam voltage level. The result is that some bunches of electrons reach the output cavity a little quicker than the average, while others reach the cavity a little slower than the average. The effect is to introduce phase modulation on the rf output, at a 360-cycle rate. Phase modulation causes sidebands, at frequencies removed from the carrier by the ripple voltage frequency. In general, only the "first order" sidebands are large enough to be meaningful. Fortunately, it is easy to compute the effect of ripple

voltage on phase modulation; and the measured results agree very well with the theoretical computations. Again, we will use the following notation:

V_o = dc beam voltage, in volts

ΔV_o = beam voltage ripple (peak-to-zero)

f_m = frequency of ripple component

θ = electrical length of the tube from input to output gap in radians (θ is about 30 radians for a three-cavity tube and 40 for a four-cavity tube)

L = physical length of tube, between input and output gaps, in cm

N = electrical length of tube in cycles

T = transit time of electron stream, between input and output gap, in seconds

$\Delta\theta$ = peak change of rf phase (due to ΔV_o), in radians

ΔF = peak change of rf frequency, due to ΔV_o

In a simple electron beam (neglecting relativistic effects), the electron velocity is:

$$v = \sqrt{\frac{2e}{m}} \times 10^7 \sqrt{V_o} = k_1 \sqrt{V_o}, \text{ cm/sec} \quad (13)$$

and

$$T = \frac{L}{v} = \frac{L}{k_1 \sqrt{V_o}} = \frac{k_2}{\sqrt{V_o}}, \text{ seconds ;} \quad (14)$$

$$\theta = 2\pi N \quad (15)$$

and

$$f_o T = N = \frac{\theta}{2\pi} \quad (16)$$

Therefore,

$$\theta = 2\pi f_o T . \quad (17)$$

Substituting (14) in (17) gives:

$$\theta = \frac{2\pi f_o k_o^2}{\sqrt{V_o}} = k_3 V_o^{-1/2} . \quad (18)$$

Taking the derivative with respect to V_o we obtain

$$\Delta\theta = -\frac{1}{2} k_3 V_o^{-3/2} \Delta V_o . \quad (19)$$

Now divide (19) by (18), and drop the negative sign for convenience, since this simply says that the effective frequency is increased by an increasing beam voltage:

$$\frac{\Delta\theta}{\theta} = \frac{1}{2} \frac{k_3 V_o^{-3/2} \Delta V_o}{k_3 V_o^{-1/2}} = \frac{1}{2} \frac{\Delta V_o}{V_o} \quad (20)$$

This allows the designer to compute the output phase change ($\Delta\theta$) relative to the average phase, with a given amount of beam voltage ripple. This is frequently called the "phase pushing" factor and after conversion from radians to electrical degrees, is often expressed in "degrees per volt."

As an example, let us consider a fairly typical 10-kW CW output tube having a θ of 40 radians, operating at 15 KV: From (20) we obtain

$$\frac{\Delta\theta}{\Delta V_o} = \frac{\theta}{2V_o} .$$

Since one radian = 57.3°

$$\frac{\Delta\theta}{\Delta V_o} = \frac{40 \times 57.3}{2 \times 15,000} = 0.076^\circ/\text{volt ripple} .$$

When solving the above equation for pushing factor it must be remembered that both ΔV_o and $\Delta\theta$ must be consistent, either both peak or both rms values. Now, by the definition of phase and frequency modulation:

$$\text{Modulation Index} = \Delta\theta = \frac{\Delta F}{f_m} . \quad (21)$$

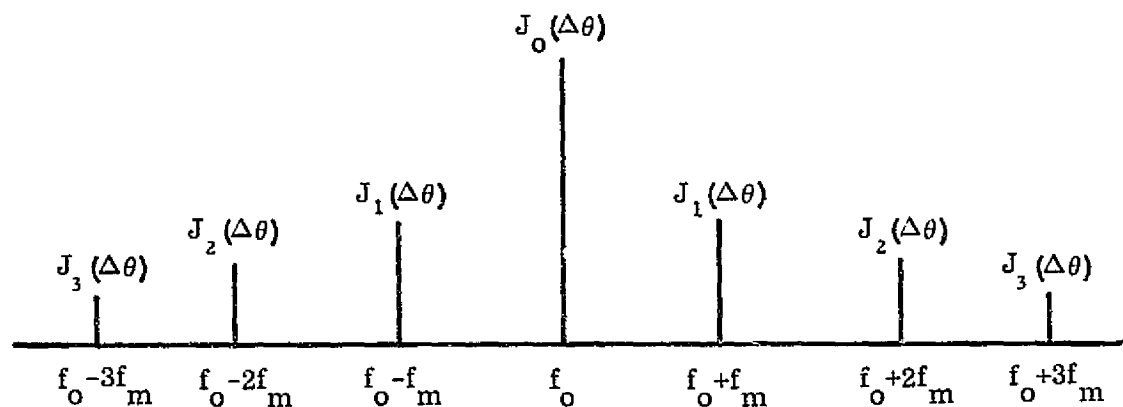
Substituting (21) in (20) gives:

$$\Delta F = f_m \frac{\theta}{2} \frac{\Delta V_o}{V_o} \quad (22)$$

Equation (22) gives the peak frequency change in the rf frequency, when the beam voltage has a peak ripple of ΔV_o volts at the ripple frequency, f_m .

The same equation applies if ΔF and ΔV_o are both in rms units.

Since this equation is for a phase-modulated rf signal, the spectrum will show sidebands at all multiples of the modulation frequency, f_m , as sketched below:



SPECTRUM OF PHASE-MODULATED SIGNAL

$J_o(\Delta\theta)$, $J_1(\Delta\theta)$, etc., are the carrier and sideband amplitudes, where the "J" terms are the usual Bessel functions of the modulation index.

Now, if the modulation index ($\Delta\theta$) is small, as will usually be the case if the ripple voltage is small, the carrier will be

$$J_o(\Delta\theta) \approx 1.0,$$

and the first-order sideband

$$J_1(\Delta\theta) \cong \frac{\Delta\theta}{2} \cong \frac{\Delta F}{2f_m} \quad (23)$$

The second and higher order sidebands will be negligible. Then, the ratio of the carrier power to the power in one of the first-order sidebands is:

$$\frac{P_o}{P_{1SB}} \text{ (db)} = 20 \log_{10} \left[\frac{J_o(\Delta\theta)}{J_1(\Delta\theta)} \right] \cong 20 \log_{10} \left[\frac{2f_m}{\Delta F(\text{peak})} \right] \quad (24)$$

It is sometimes convenient to work in rms terms, instead of peak. Under these circumstances, (24) becomes:

$$\frac{P_o}{P_{1SB}} \text{ (db)} \cong 20 \log_{10} \left[\frac{2f_m}{\sqrt{2} \Delta F(\text{rms})} \right] \cong 20 \log_{10} \left[\frac{\sqrt{2} f_m}{\Delta F(\text{rms})} \right] \quad (25)$$

Also: The ratio of the power in the carrier to the power in both first-order sidebands is:

$$\frac{P_o}{P_{2SB}} \text{ (db)} \cong 20 \log_{10} \left[\frac{2f_m}{\sqrt{2} \Delta F(\text{peak})} \right] \cong 20 \log_{10} \left[\frac{\sqrt{2} f_m}{\Delta F(\text{peak})} \right] \quad (26)$$

or, in rms units:

$$\frac{P_o}{P_{2SB}} \text{ (db)} \cong 20 \log_{10} \left[\frac{\sqrt{2} f_m}{\sqrt{2} \Delta F(\text{rms})} \right] \cong 20 \log_{10} \left[\frac{f_m}{\Delta F(\text{rms})} \right] \quad (27)$$

Substituting (22) in (26) gives:

$$\frac{P_o}{P_{2SB}} \text{ (db)} \cong 20 \log_{10} \left[\frac{2\sqrt{2} V_o}{\theta \Delta V_o(\text{peak})} \right] \cong 20 \log_{10} \left[\frac{2V_o}{\theta \Delta V_o(\text{rms})} \right] \quad (28)$$

Equation (28) gives the ratio of the power in the carrier to the power in both first-order sidebands in terms of the rms ripple voltage on the beam supply, when the ripple is small relative to the total beam voltage. The formula applies to each of the ripple-voltage frequencies (f_m), and is useful when the ripple voltage has been wave-analyzed to determine the magnitude of the ripple components at each of the ripple frequencies.

Let us use the same parameters given in the previous example for AM sideband power:

$$V_o = 20,000 \text{ volts}$$

$$\Delta V_o = 10 \text{ volts, peak-to-zero ripple}$$

$$f_m = 360 \text{ cycles}$$

$$\theta = 40 \text{ radians (assuming a four-cavity amplifier)}$$

Solving (20) for $\Delta\theta$ gives:

$$\Delta\theta = \frac{\theta}{2} \frac{\Delta V_o}{V_o} = \left(\frac{40}{2}\right) \left(\frac{10}{20,000}\right) = 0.01 \text{ radians}$$

$$= 0.01 \times 57.3^\circ = 0.573^\circ = \text{peak phase excursion,}$$

Solving (21) results in:

$$\Delta F = \Delta\theta f_m = 0.01(360) = 3.6 \text{ cycles} = \text{peak frequency deviation.}$$

Solving Equation (28):

$$\frac{P_o}{P_{2SB}} (\text{db}) = 20 \log_{10} \left[\frac{2.828 \times 20,000}{40 \times 10} \right] = 43 \text{ db.}$$

Consequently the sum of the power in both first-order phase-modulation sidebands is 43 db below the power of the carrier. The power in each of the first-order sidebands is 46 db below the carrier and the sidebands will be located at $f_o \pm 360$ cycles. By phase-modulation theory we know that there will also be sidebands at $f_o \pm 720$, $f_o \pm 1080$, cycles etc. However the power in these sidebands will be very low compared to the power in the carrier and the power in the first-order sidebands.

